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PROGRESS REPORT FOR THE CONFERENCE ON POLLUTION OF RARITAN BAY AND ADJACENT INTERSTATE WATERS. SECOND SESSION

Public Health Service
Metuchen, New Jersey

April 1963

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PROGRESS REPORT
for
The Conference on Pollution of Raritan Bay
and
Adjacent Interstate Waters

Second Session

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Public Health Service

Division of Water Supply and Pollution Control

Raritan Bay Project

Metuchen, New Jersey

April 1963

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INTRODUCTION

A conference concerning the pollution of interstate waters of Raritan Bay (New York, New Jersey) was held under authority of section 8 of the Federal Water Pollution Control Act, in New York City on August 22, 1961. Conferees present represented the

New Jersey State Health Department

New York State Department of Health

Interstate Sanitation Commission
(New York, New Jersey, Connecticut)

U.S. Department of Health, Education
and Welfare.

The conferees, pursuant to a review of existing water conditions, concluded that "Scientific data, taking into account a wide range of factors and technological problems, including health, conservation, water policy and uses, and industrial processes are urgently needed, and are the critical issue in further control of pollution of these waters."

The conferees agreed that the Public Health Service of the U.S. Department of Health, Education and Welfare would undertake an investigation of these waters to accumulate the required data. The investigation was to be conducted in collaboration with the three other agencies taking part in the conference. The conferees also agreed to reconvene in approximately one year, on the call of the Chairman, in order to evaluate investigational progress and to consider recommendations of further action.

Accordingly, the Public Health Service established an on-site project; it secured, equipped and staffed a laboratory able to conduct the investigation. The planned objective was to develop scientific data necessary for the establishment, by the conferees, of an effective program for the abatement and control of pollution in the waters of Raritan Bay.

The conference call describes the area to be studied as the Raritan Bay and all its intra- and inter-state tributaries which cause or contribute to pollution in the bay.

This report summarizes the progress made in the investigation, from the time of project inception through December 31, 1962. During the first year of activity, the following studies were conducted:

1. An intensive bacteriological sampling program of Raritan Bay, the shoreline, entrant waters and the sewage treatment plants discharging into the bay to determine the bacterial densities in these waters.

2. A series of dissolved oxygen tests of the bay and biochemical oxygen demand tests of sewage treatment plant effluents.

3. Current and dispersion studies to trace water movements in Raritan Bay and movements from Arthur Kill into the bay.

4. A biological investigation to define the area of biological concern for purposes of further study.

SUMMARY

High densities of fecal bacteria were found in the waters of Raritan Bay; they were highest in the vicinity of the Narrows, the Raritan River and Arthur Kill.

High densities of fecal bacteria were found in the waters of the bathing beaches at the northern end of Staten Island and in the Perth Amboy area.

Low dissolved oxygen was observed in the waters of Raritan Bay at the confluence of Arthur Kill and the Raritan River. These dissolved oxygen levels were below the standards (50% saturation) set by the Interstate Sanitation Commission.

Current and dispersion studies, using dye, showed that waters of Arthur Kill have an effect on the waters of the western end of Raritan Bay. Further, dye released in the waters of the western end of Raritan Bay were found to be dispersed uniformly in this area after a period of five days.

Significant densities of pollution-tolerant biological organisms were observed in the area of the bay adjacent to the Narrows. Phytoplankton concentrations, found existent in the bay, are lower than those normally found in waters of good quality.

Three treatment plants failed to meet the Interstate Sanitation Commission standard for suspended solids removal during 24-hour sampling. Spot sampling at treatment plants revealed lower bacteriological removals and lower levels of chlorine residuals than had been observed during 24-hour studies.

Approximately ninety five percent of the total biochemical oxygen demand discharged directly to bay waters by treatment plants originates from effluents of the Perth Amboy and Middlesex County Sewerage Authority treatment plants. This load--equivalent to a population of one million persons--contributes to the low dissolved oxygen conditions observed in the western end of Raritan Bay.

Raw sewage produced by three thousand persons in the Tottenville area of Staten Island was found to contain high levels of coliforms and fecal bacteria.

CONCLUSIONS

These studies demonstrated that pollution interfering with the legitimate water uses of Raritan Bay come from (1) direct discharges into the bay of inadequately treated sewage from treatment plants tributary to the bay, (2) pollution from the upper New York Harbor entering the bay through the Narrows, (3) pollution entering the bay from Arthur Kill, and (4) pollution entering the bay from the Raritan River.

Current and dispersion studies reveal that pollution entering the water anywhere below the Outerbridge in Arthur Kill, or in the bay west of Seguine Point, could diffuse in an approximately uniform manner throughout the entire inner area of the bay, the Raritan River and Arthur Kill.

The high densities of fecal bacteria and low dissolved oxygen saturation found in the bay waters indicate conditions of pollution are present at the same levels that existed during the 1961 outbreak of hepatitis traced to consumption of raw shellfish taken from these bay waters. Therefore, it can be reasonably assumed that these conditions still remain a health hazard at bathing beaches, preclude the operation of a safe shellfish industry and interfere with other recreational uses, including fishing and boating, of the waters of Raritan Bay.

Therefore, all four principal sources of pollution (direct discharges to the bay, the Narrows, the Raritan River and Arthur Kill) must be brought under control before the waters of Raritan Bay can be restored to their full legitimate uses for swimming, shellfish harvesting, boating, fishing, and other recreational purposes.

More effective treatment of present sewage discharges into the bay must be provided. All sources of pollution in the upper New York Harbor, Arthur Kill and the Raritan River, which may have deleterious effects on the waters of Raritan Bay, or the use of these waters, must be identified and brought under control.

STUDY PROGRAMS AND PROCEDURES

The size of the Raritan Bay study area (more than 90 square miles) required segmentation of the investigations to permit thorough coverage of the problem's many aspects. The required basic data included: characterization of the water quality and waste effluents, the effect of tributary bodies of water, effect of environmental factors, other transient effects such as storm water runoff and wastes from small and large vessles. The study was divided into a series of efforts, each directed to the sequential solution of each of these problem areas.

During the first year, studies were directed toward discovering the effects of water movements within the bay, and of entrant waters from the tributaries. Bacteriological, chemical and biological characterization of the bay waters was also a first year objective--as was the characterization of major treatment plant effluents directly tributary to the bay.

The bacteriological and chemical investigations undertaken in the bay consisted of weekly samplings at a grid of stations in the bay and along the shoreline. Simultaneous investigations were made of treatment plant effluents. Additional samplings were made at the treatment plants on a 24-hour basis to determine plant efficiencies. The sampling program and locations are detailed in the appendix; station locations are shown in Figure 1.

Standard sampling procedures and laboratory methods were used within the recommendations of Standard Methods for the Examination of Water and Wastewater, 11th Edition. Sampling procedures, laboratory procedures, and deviations where necessary are detailed in the appendix.

Procedures

Three procedures were used to describe the bacteriological quality of bay waters: the "Confirmed Test" for coliforms by the multiple tube method; tests for fecal coliforms by transfer from the positive primary fermentation media to selective media at elevated temperature; determination of fecal streptococcus by use of membrane filter procedures. Random colony picks of the organisms were identified by appropriate biochemical tests in accordance with standard practices.

Chemical and physical tests used to characterize bay waters included: dissolved oxygen, conductivity, chloride content, temperature. These test results were converted, by standard tables, to percent saturations of dissolved oxygen.

RARITAN BAY STUDY RESULTS

Bay Waters

Results of the bacteriological and chemical analyses are summarized for the present reporting period (June-December, 1962) in appendix tables; they are further summarized in a series of figures and charts similar to those used in the first conference report. All bacteriological data are presented as geometric means unless stated otherwise. Chemical data are summarized by arithmetic averages.

Figures 2 and 3 present the confirmed and fecal coliform data in a series of iso-intensity lines (lines of equal density of bacterial organisms). Figure 2 shows that high densities of organisms --over 1,000 per 100 milliliters--extend from the Narrows area to a line running from above the Great Kills beach to the tip of Sandy Hook. High levels are also seen in the area of the junction of Arthur Kill and the Raritan River. Figure 3 shows substantially the same overall pattern for fecal coliforms, but in a slightly lower order of magnitude.

Figures 4, 5 and 6 are graphical presentations of the following cross sections: the bay along the New York-New Jersey state line; the Raritan Bay channel; the north-south profile of the eastern extreme of the bay from Staten Island to Sandy Hook. These figures include the geometric means of the confirmed and fecal coliforms, and of fecal streptococcus. All graphs indicate relatively high levels of organisms at the two extremities of the bay, and decreasing densities toward the center of the bay. The lowest observed levels were in the area east of Seguine Point and west of Great Kills, Staten Island. This area closely approximates the original open shellfish area.

Thirteen of the 54 stations sampled lie within the area of the original open shellfish beds. Twelve of these thirteen stations do not meet the levels of water quality recommended for shellfish waters by the United States Public Health Service (Table 1). Levels of fecal coliform and fecal streptococcus observed in this area would also make questionable the harvesting of shellfish from these waters.

The high levels of bacterial contamination (Figures 4, 5 and 6) indicate that the major effects on Raritan Bay are in the area of the Narrows and the area of the junction of the Raritan River and Arthur Kill. This parallels results shown in Figures 2 and 3. Figure 6 in particular indicates material coming from the Narrows; increasing levels, with increasing proximity to the Narrows, demonstrate the significance of this source of pollution on bay waters.

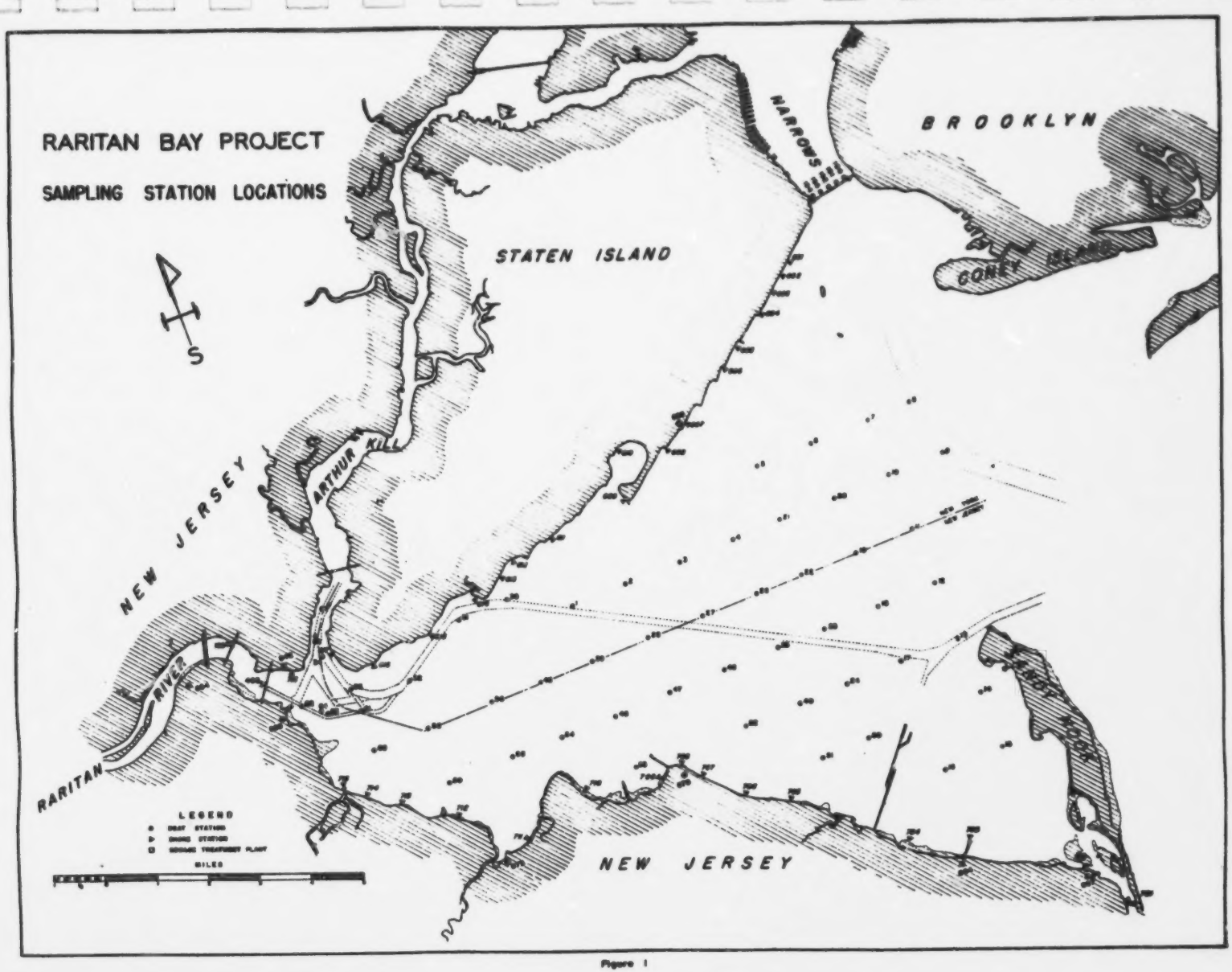
RARITAN BAY PROJECT
SAMPLING STATION LOCATIONS
N
S
STATEN ISLAND
BROOKLYN
HARROWS
CONEY ISLAND
NEW JERSEY
ARTHUR KILL
RARITAN RIVER
SANDY HOOK
NEW JERSEY
LEGEND
MILES

Figure 1

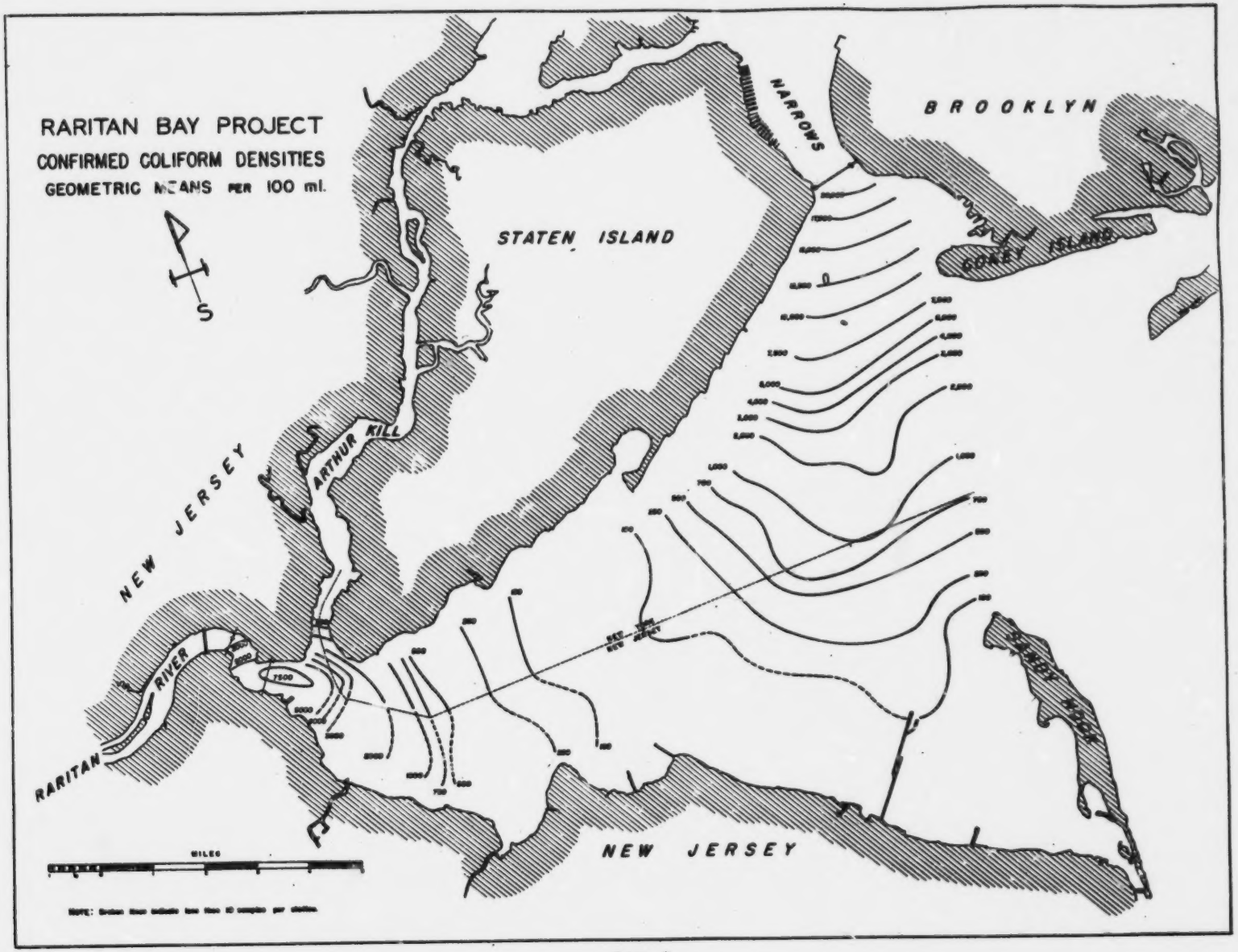
RARITAN BAY PROJECT
CONFIRMED COLIFORM DENSITIES
GEOMETRIC MEANS PER 100 ml.
N
S
STATEN ISLAND
BROOKLYN
NARROWS
GOWANUS
GOWANUS
GOKEY ISLAND
NEW JERSEY
ARTHUR KILL
RARITAN RIVER
7500
SANDY HOOK
NEW JERSEY
MILES

Figure 8

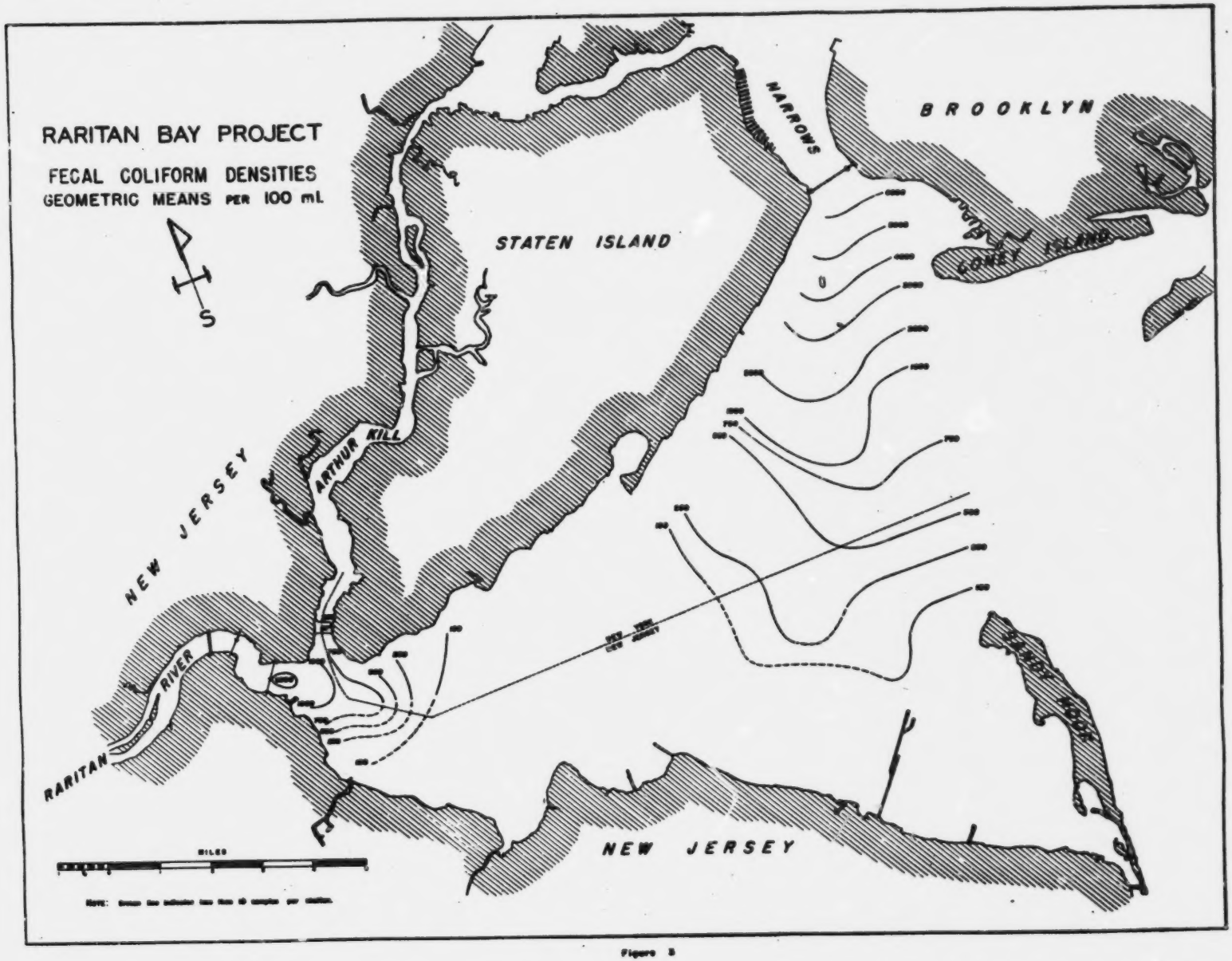
RARITAN BAY PROJECT
FECAL COLIFORM DENSITIES
GEOMETRIC MEANS PER 100 ml
N
S
STATEN ISLAND
NEW JERSEY
ARTHUR KILL
NARROWS
BROOKLYN
CONEY ISLAND
RARITAN
RIVER
SANDY HOOK
NEW JERSEY
MILES

Figure 3

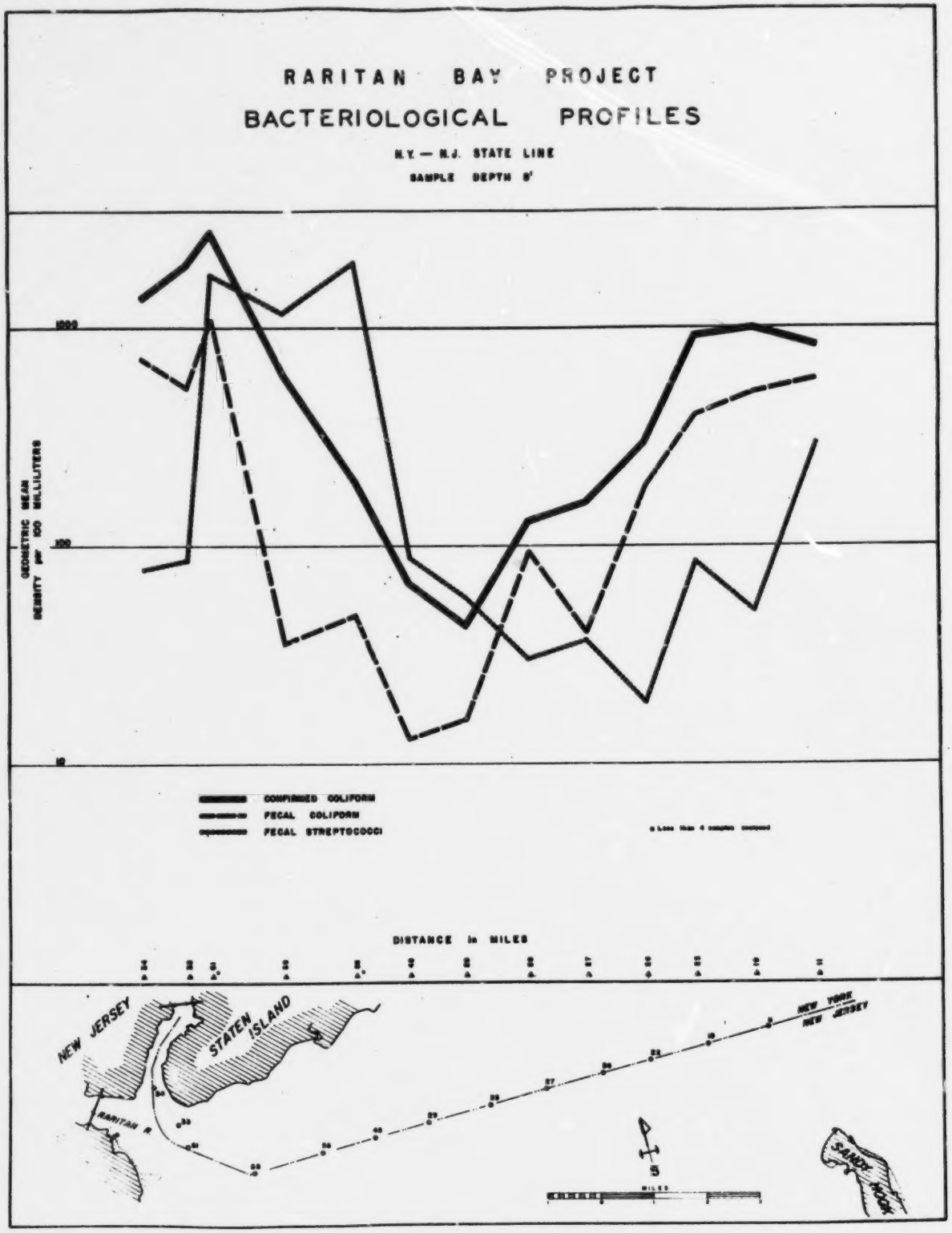
RARITAN BAY PROJECT
BACTERIOLOGICAL PROFILES
N.Y. — N.J. STATE LINE
SAMPLE DEPTH 0'
GEOMETRIC MEAN
DENSITY per 100 MILLILITERS
1000
100
10
CONFIRMED COLIFORM
FECAL COLIFORM
FECAL STREPTOCOCCI
DISTANCE in MILES
NEW JERSEY
STATEN ISLAND
RARITAN R.
NEW YORK
NEW JERSEY
SANDY HOOK
5
MILES

Figure 4

6-E

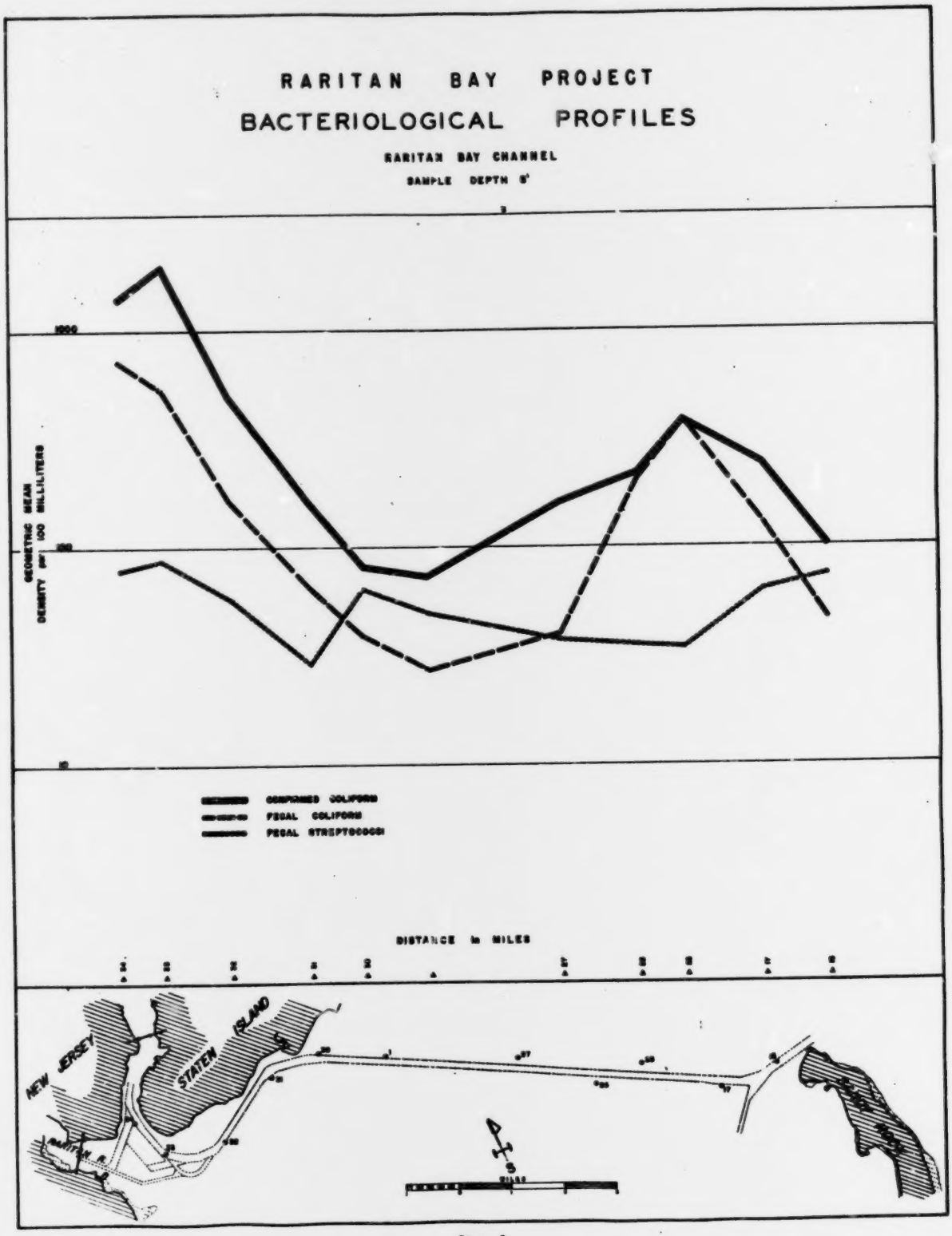
RARITAN BAY PROJECT
BACTERIOLOGICAL PROFILES
RARITAN BAY CHANNEL
SAMPLE DEPTH 5'
GEOMETRIC MEAN
DENSITY per 100 MILLILITERS
1000
100
10
CONFIRMED COLIFORM
FECAL COLIFORM
FECAL STREPTOCOCCI
DISTANCE in MILES
NEW JERSEY
STATEN ISLAND
RARITAN R.
SANDY HOOK

Figure 6

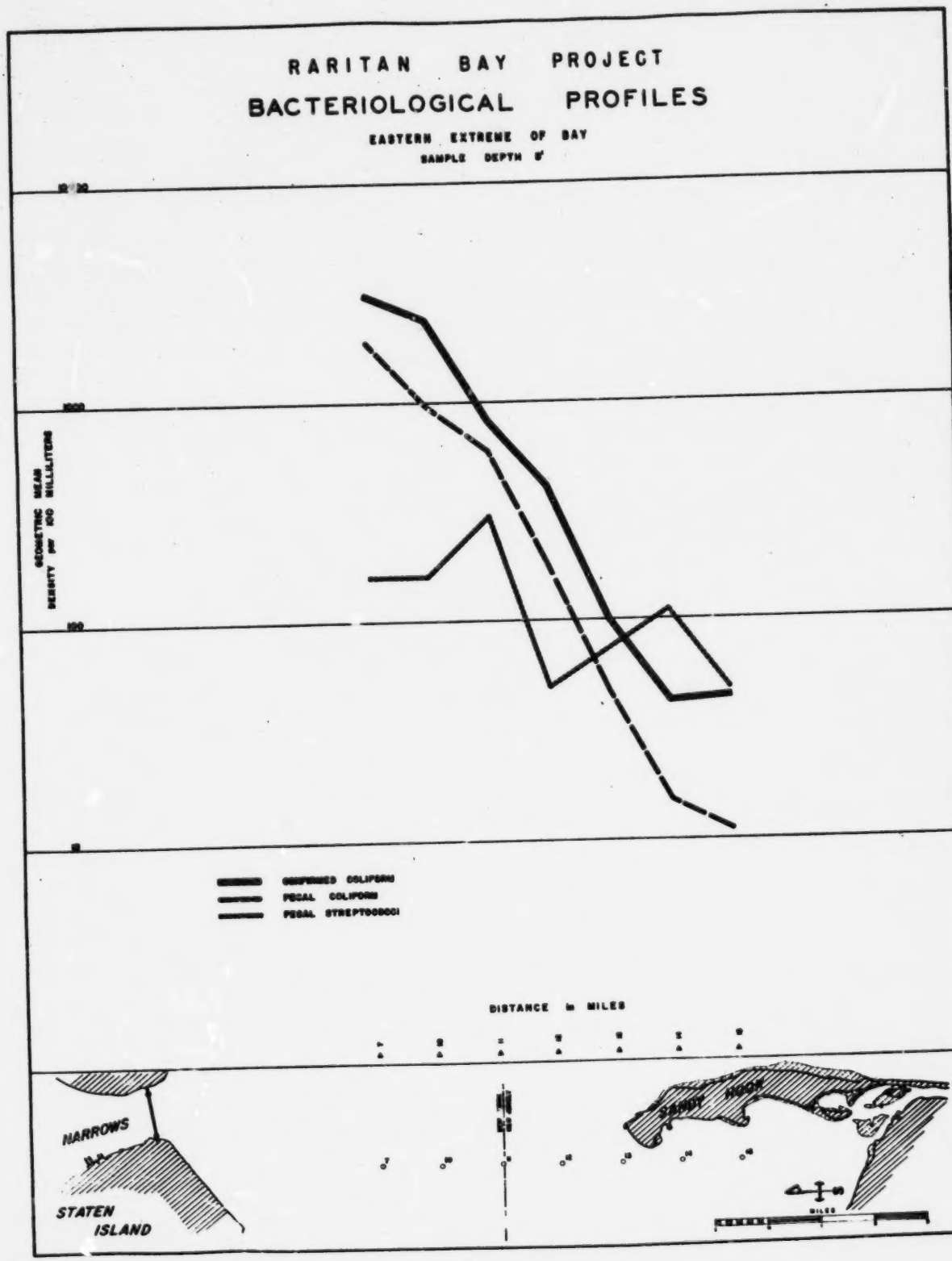
RARITAN BAY PROJECT
BACTERIOLOGICAL PROFILES
EASTERN EXTREME OF BAY
SAMPLE DEPTH 8'
GEOMETRIC MEAN DENSITY PER 100 MILLILITERS
DISTANCE in MILES
HARROWS
STATEN ISLAND
SANDY HOOK

Figure 6

RARITAN BAY PROJECT

TABLE 1. BACTERIOLOGICAL DATA FOR STATIONS IN SHELLFISH AREA*

Densities per 100 milliliters

Station	CONFIRMED COLIFORM MPN			FECAL COLIFORM MPN			FECAL STREPTOCOCCUS		
	Number Samples	Median	Percent Above 230	Number Samples	Median	Percent Above 230	Number Samples	Median	Percent Above 230
1S	20	79	25	19	20	5	25	10	16
1D	20	90	30	19	27	11	18	20	11
2S	20	56	35	18	20	17	19	10	37
2D	20	41	35	17	20	18	24	35	29
3S	20	230	45	18	35	22	24	25	21
3D	19	80	42	16	65	25	17	10	35
28S	11	220	45	8	130	25	14	10	14
28D	13	240	62	9	220	44	17	70	29
29S	13	50	23	9	22	0	17	40	12
29D	13	79	15	9	33	0	15	10	0
30S	16	68	19	11	33	9	15	30	27
30D	15	110	33	12	30	17	20	30	25
31S	16	150	38	11	49	18	20	35	5
31D	16	79	31	12	36	17	15	30	7
45	5	70	20	5	11	0	6	30	17
46	4	33	25	4	13	25	5	10	20

RARITAN BAY PROJECT

TABLE 1. BACTERIOLOGICAL DATA FOR STATION IN SHELLFISH AREA* (Concl.)

Densities per 100 milliliters

Station	CONFIRMED COLIFORM MPN			FECAL COLIFORM MPN			FECAL STREPTOCOCCUS		
	Number Samples	Median	Percent Above 230	Number Samples	Median	Percent Above 230	Number Samples	Median	Percent Above 230
47	5	46	40	5	8	0	6	50	17
48	4	41	0	4	30	0	5	10	0
52	5	33	20	5	7	20	5	160	20
54	4	155	25	4	14	0	5	2300	80

*New York-New Jersey beds closed to shellfishing in May-June 1961.

Dissolved oxygen studies were also made, concurrently with the bacteriological studies discussed above; the results are shown as arithmetic averages of all samples collected during the period of studies (Figure 7). A profile of the dissolved oxygen pattern observed during the survey of August 22, 1962--the week during which the peak water temperature was observed--is shown in Figure 8. This approximates the minimal condition of dissolved oxygen observed generally in the bay; however, local areas revealed more critical conditions during September and October. The dissolved oxygen data are summarized in an appendix table.

The considerable influence of flows from the Narrows, and from the areas of the junction of Arthur Kill and the Raritan River, on the waters of Raritan Bay proper are shown in Figures 7 and 8. These profiles indicate substantially the same patterns of influence shown by the bacteriological data.

Figure 8 shows an area in the eastern end of the bay where observed levels of dissolved oxygen were less than 50%. Levels less than 75% prevailed throughout the eastern end of the bay; a large area of the western end of the bay also showed saturation levels of approximately 50%. The oxygen levels observed approach, and in some cases are less than, the standards set for this body of water by the Interstate Sanitation Commission. Low dissolved oxygen levels and high bacterial densities parallel one another throughout a major portion of the bay, stressing the fact that these two problems are closely interrelated.

Shoreline Waters

Analyses were also conducted on samples, taken on a weekly basis, from a series of shore stations on both the Staten Island and New Jersey shorelines. All three bacteriological indicators (see appendix charts) are also summarized as graphical profiles in Figures 9 and 10. The Staten Island shoreline (Figure 9) exhibits the same general pattern of high levels of bacteriological organisms already noted in the Narrows area; lower levels occur in the central area of the bay, in the vicinity of Great Kills. The New Jersey shoreline (Figure 10) reveals essentially lower levels than are found on the Staten Island shoreline at the eastern extremity--but shows higher levels in the western extremity.

A beach with a count of 1,000 or less organisms per 100 ml is classified as "approved" according to the standard used by the New York City Department of Health. Four of the sampling stations at the eastern end of Staten Island yielded counts exceeding this approved level. The bathing beach at Perth Amboy, Station 716, also exceeds this level.

It must be recognized that, in addition to the observed high coliform counts, high orders of fecal coliforms and fecal streptococcus were also encountered--in many cases of the same order of magnitude as the confirmed coliform counts. The sanitary significance of the presence of organisms, known to be of fecal origin from warm-blooded animals and humans, is that this represents actual pollution of these waters by untreated or inadequately treated sewage.

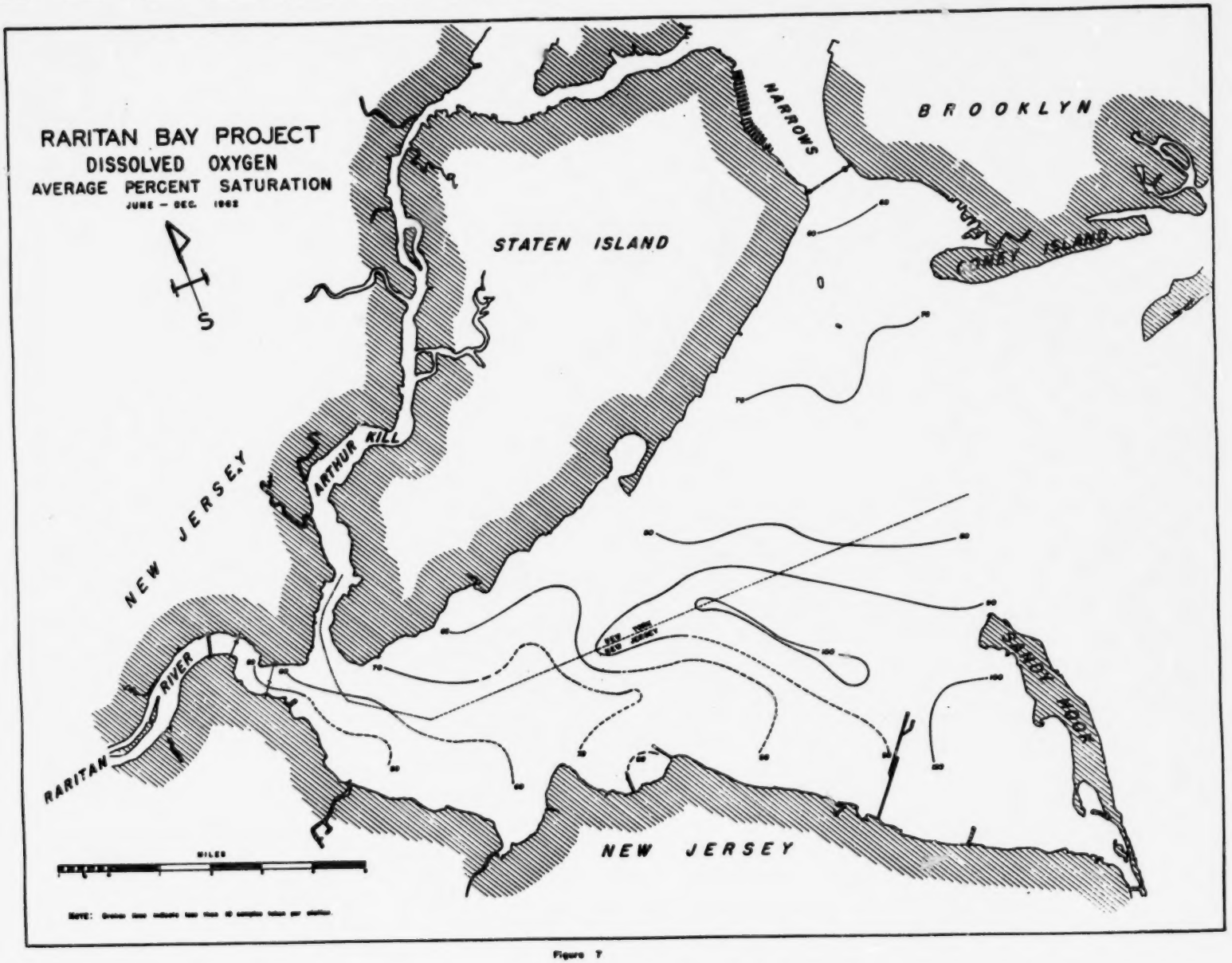
RARITAN BAY PROJECT
DISSOLVED OXYGEN
AVERAGE PERCENT SATURATION
JUNE - DEC. 1962
N
S
NARROWS
BROOKLYN
STATEN ISLAND
CONEY ISLAND
ARTHUR KILL
NEW JERSEY
RARITAN RIVER
SANDY HOOK
NEW JERSEY
MILES

Figure 7

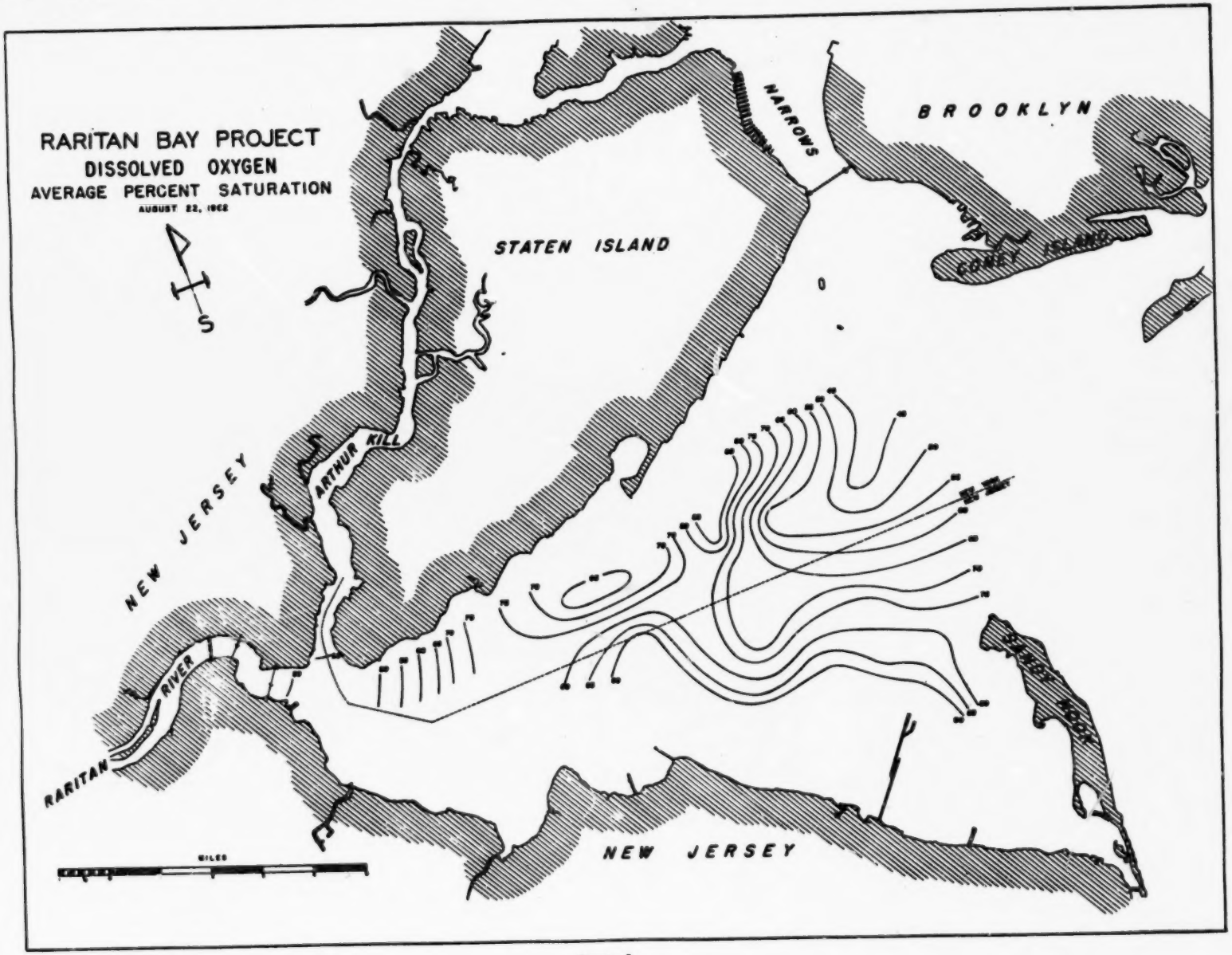
RARITAN BAY PROJECT
DISSOLVED OXYGEN
AVERAGE PERCENT SATURATION
AUGUST 22, 1962
N
S
STATEN ISLAND
NARROWS
BROOKLYN
CONEY ISLAND
ARTHUR KILL
NEW JERSEY
RARITAN RIVER
SANDY HOOK
NEW JERSEY
MILES

Figure 6

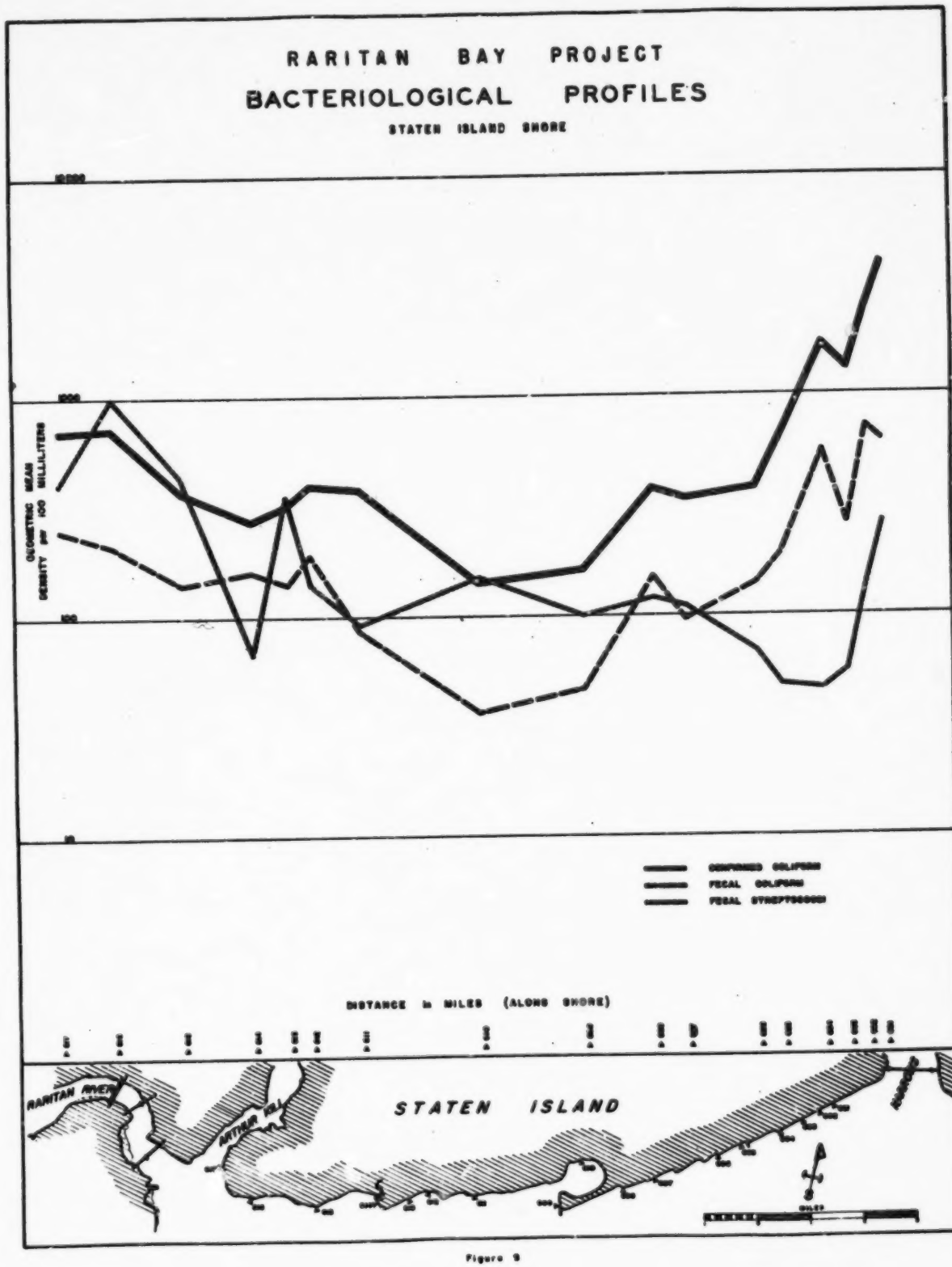
RARITAN BAY PROJECT
BACTERIOLOGICAL PROFILES
STATEN ISLAND SHORE
GEOMETRIC MEAN DENSITY per 100 MILLILITERS
DISTANCE in MILES (ALONG SHORE)
STATEN ISLAND
RARITAN RIVER
ARTHUR KILL

Figure 9

RARITAN BAY PROJECT

BACTERIOLOGICAL PROFILES

NEW JERSEY SHORE

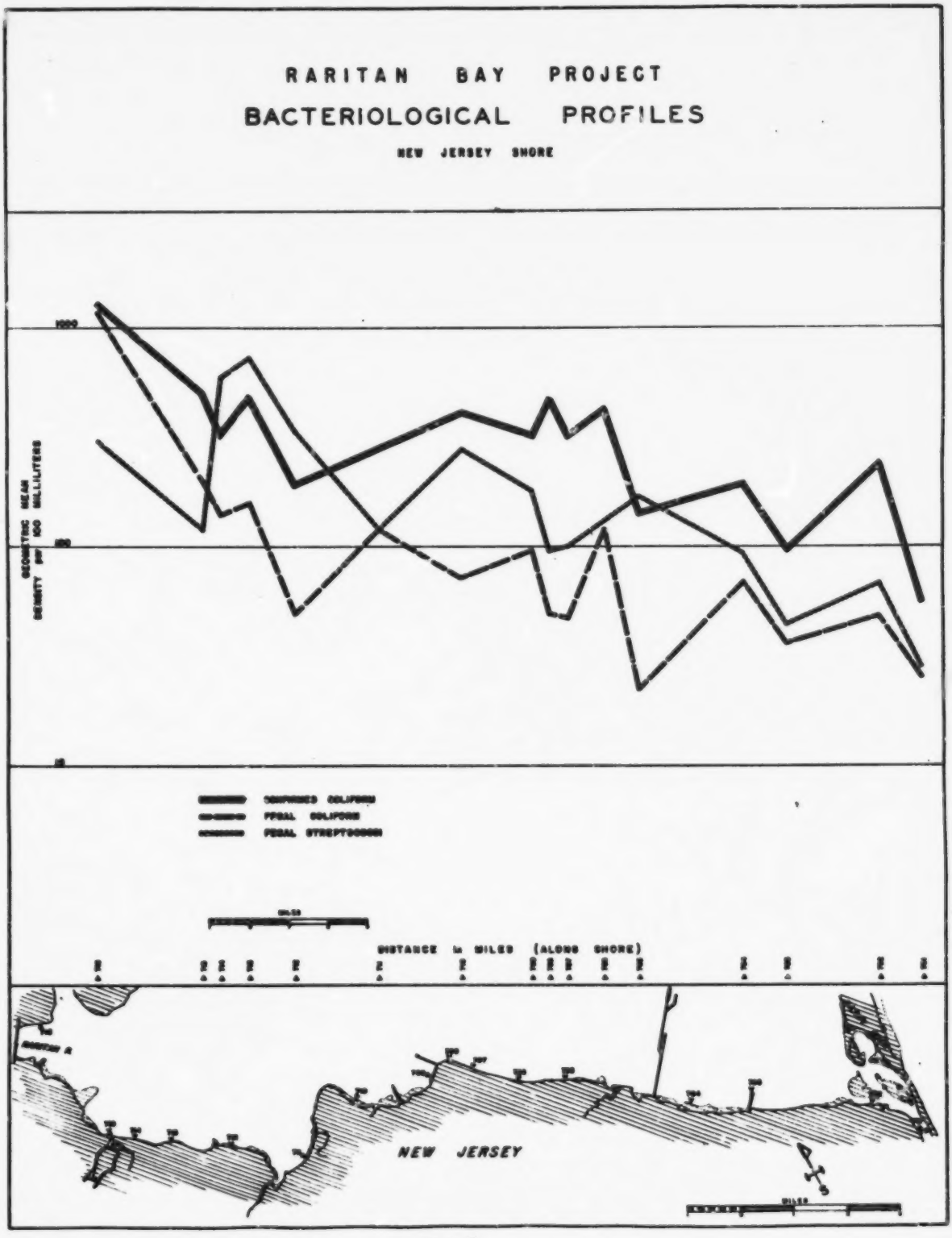

Figure 10

Current and Dispersion Studies

A current and dispersion study was conducted in the western end of Raritan Bay; dye was released at high water slack, on August 15, 1962 in the area of the Ward Point secondary channel. Dispersion of the dye was monitored visually and photofluorometrically over a period of four days. The dye moved as a fairly well defined mass; the outer limits were readily discernible during the first day.

During the second and third days the dye became progressively more diffused; it was distributed laterally, longitudinally and vertically throughout the inner bay (Figure 11).

At the end of this three-day period the dye was still discernible throughout the area at the following locations: (1) the Raritan River at Victory Bridge, (2) Arthur Kill at Tufts Point, (3) Raritan Bay at Seguine Point, Staten Island, (4) Raritan Bay off Keyport, N. J. After five tidal cycles, peaking was still discernible just east of the original dye release area. The net movement of the dye mass had been approximately one-half mile seaward over five tidal cycles. This indicates a net seaward movement of the dye at a rate of approximately one-tenth mile per tidal cycle.

This dye study--together with previously developed information--indicates that pollutants released anywhere in the western end of the bay can diffuse through the entire inner area of the bay and through the lower ends of Arthur Kill and the Raritan River. Moreover, if this material is released on a continuous basis, it is retained in the area with a net seaward movement of only one-tenth mile per tidal cycle. (See appendix for further details.)

Biological Studies

Preliminary biological studies were made at six stations in the bay and its adjacent waters (Figure 12). Analyses of phytoplankton and benthos (bottom organisms) indicate that organisms associated with areas strongly affected by domestic sewage are found in the bay at Station II; this is an area shown to be affected bacteriologically and chemically by waters entrant from the Narrows.

Phytoplankton found in a normal, healthy state in the eastern end of the bay are found in poor physiological condition in the western areas of the bay. This indicates that conditions adverse to the growth of phytoplankton populations exist in these waters. The concentrations of phytoplankton found existent in the bay are of much lower order than are found in other bays of similar size--although nutrient levels in Raritan Bay appear to be large enough to sustain a greater population. (Biological data are detailed in the appendix.)

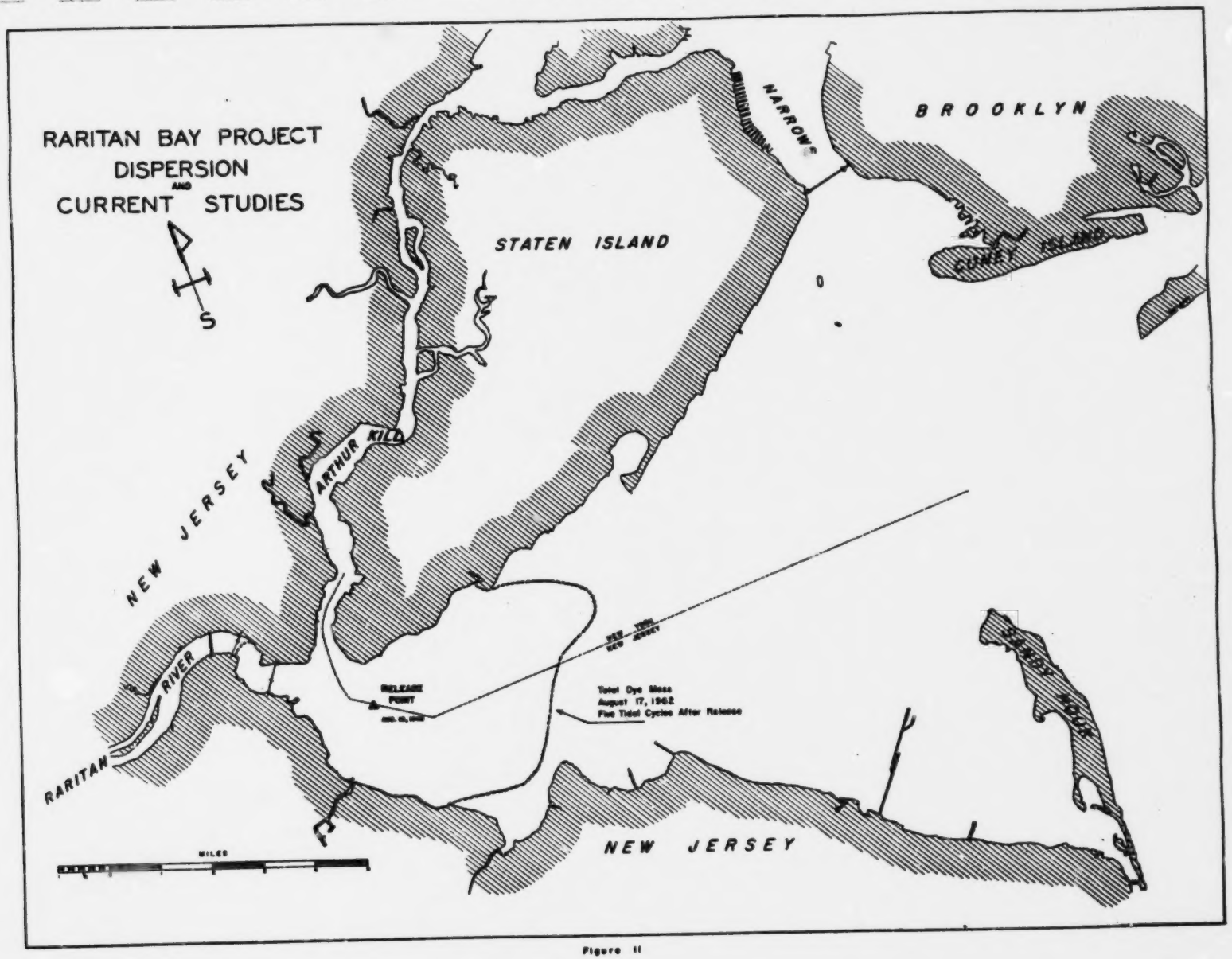

Figure 11

B-01

RARITAN BAY PROJECT
BIOLOGICAL SAMPLING STATIONS

STATION	DEPTH at MLW	LOCATION
I	15'	RED BANK
II	20'	WEST BANK LIGHT
IIA	10'	GREAT KILLS LIGHT
III	23'	CHAPEL HILL CHANNEL
IIIA	10'	MID BAY
IV	7'	KEYPORT HARBOR
V	12'	GREAT BEDS, ANCHORAGE
VA	35'	ARTHUR KILL, TOTTENVILLE FERRY
VI	12'	JERSEY CENTRAL R.R. BRIDGE
VII	95'	THE NARROWS

C-01

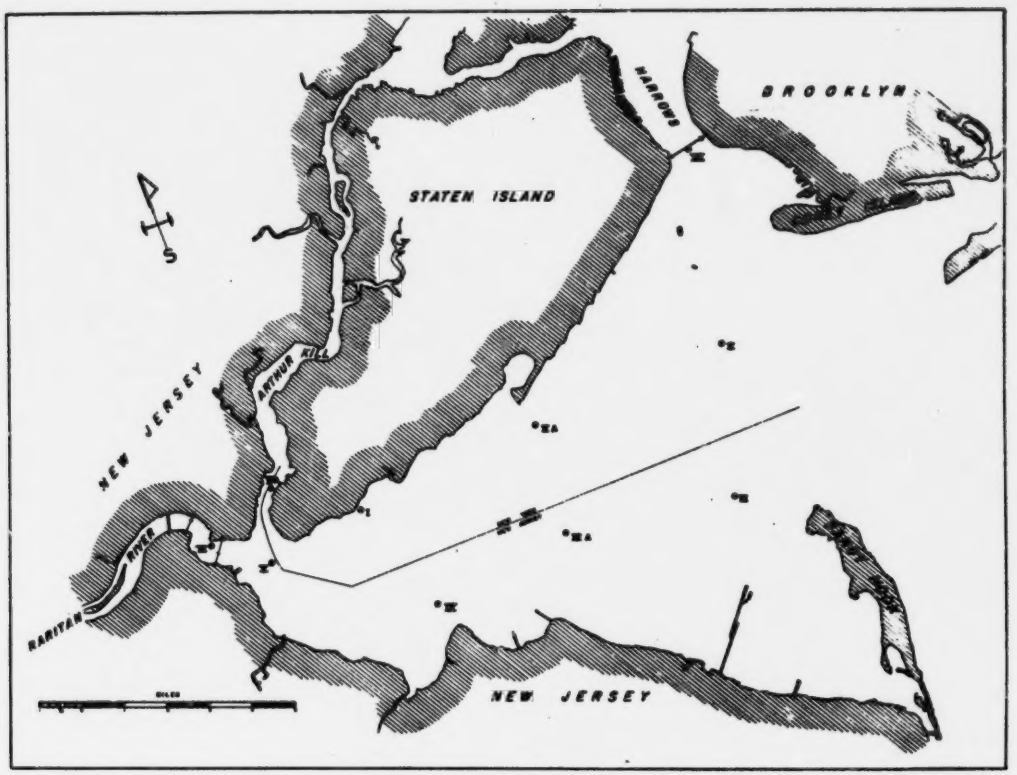

Figure 12

Entrant Waters

The effect of entrant waters on the quality of Raritan Bay waters has already been discussed. To explore this problem further, a current and dispersion study was conducted to determine the dispersion of dye within the waters of Arthur Kill in order to determine the path of flow of these waters. Dye was released in Arthur Kill just below Outerbridge Crossing at low-water slack on October 17, 1962. The release was timed to enable observation of the outward (down-Kill) movement of the dye under the most adverse conditions of current movement. Under these conditions the dye must first transit up-stream with the incoming current, then reverse at the turn of tide and run down-stream out of the Kill.

The dye was monitored visually and photofluorometrically during a period of four days. The dye dispersed throughout the entire Kill area as far north as the Goethals Bridge (Figure 13). At the end of four days the dye was dispersed uniformly through the entire western end of Raritan Bay--in the same areas and in approximately the same concentrations that were found after the dye release was made in the bay on August 15 (Figure 11). The peak of the dye concentration (after four days) was located in the deep water anchorage southeast of Perth Amboy. The net seaward movement of the dye mass was approximately nine miles in a period of eight tidal cycles--approximately one mile per tidal cycle.

The entrant waters of Raritan River, Arthur Kill and the Narrows were also sampled bacteriologically and chemically during the course of the project studies. The analyses are summarized in appendix tables.

Bacteriological concentrations of 20,000 per 100 ml were found in the Narrows. These concentrations--excessive by any standards--were previously shown to be one of the major factors affecting the quality of water in the eastern end of Raritan Bay. The observed organism concentrations result from the release of raw or inadequately treated sewage, discharged into the waters of the upper harbor, which transit seaward through the Narrows. Currents in the Narrows displace, westward, a portion of those waters originating in the upper bay.

There are low levels of dissolved oxygen saturation in the Raritan River and in the southern end of Arthur Kill; these result from discharge and decay of oxygen-consuming materials in the tributary waters.

Sewage Treatment Plants

The operations of all treatment plants tributary to bay waters were studied; spot sampling was conducted at all plants, and 24-hour sampling was done at each of the major (over 0.25 mgd) systems in the area.

Weekly observations dealt with the bacteriological contents, suspended solids and biochemical oxygen demand concentrations of the plant effluents. Twenty-four hour sampling sought to determine the removal efficiencies of the major treatment plants in terms of bacteriological, suspended solid and biochemical oxygen demand contents. Chlorine residuals of the effluents were also measured in order to determine disinfection effectiveness.

The bacteriological data and chlorine residual information are summarized in a frequency table (Table 2). This table shows that the Atlantic Highlands and Keansburg treatment plants failed to meet the Interstate Sanitation Commission's standard of 100/100 ml, for more than 50% of the samples collected during 24-hour surveys. The Keansburg and Highlands plants failed to meet the Interstate Sanitation Commission's standard during spot sample checks.

Thirty-nine percent of the chlorine residuals at the Keansburg plant (24-hour surveys) were 0.5 mg/ml or less. The bacteriological data for confirmed coliforms, fecal coliforms and fecal streptococcus at all plants are summarized in tables in the appendix.

The chemical results for the major treatment plants (24-hour surveys) are summarized in Table 3. The measurements are expressed as pounds-per-day influent to, and effluent from, the plant. Percent removals are also indicated in the same table.

The Interstate Sanitation Commission standard for Class A waters is 60% reduction of total suspended solids. The Keansburg, Atlantic Highlands and Highlands treatment plants failed to meet this standard on each and every one of the sampling occasions.

There are no standards existing for the discharge of biochemical oxygen demanding materials in the effluent; but it should be noted that two plants--Perth Amboy and Middlesex County Sewerage Authority plants--contributed 95% of the total biochemical oxygen demand loading from municipal treatment plants directly tributary to the bay. The combined loading of these two plants is equivalent to a discharge for more than one million persons.

As already noted in discussion of the bay dissolved oxygen patterns, these two plants contribute to the depressed dissolved

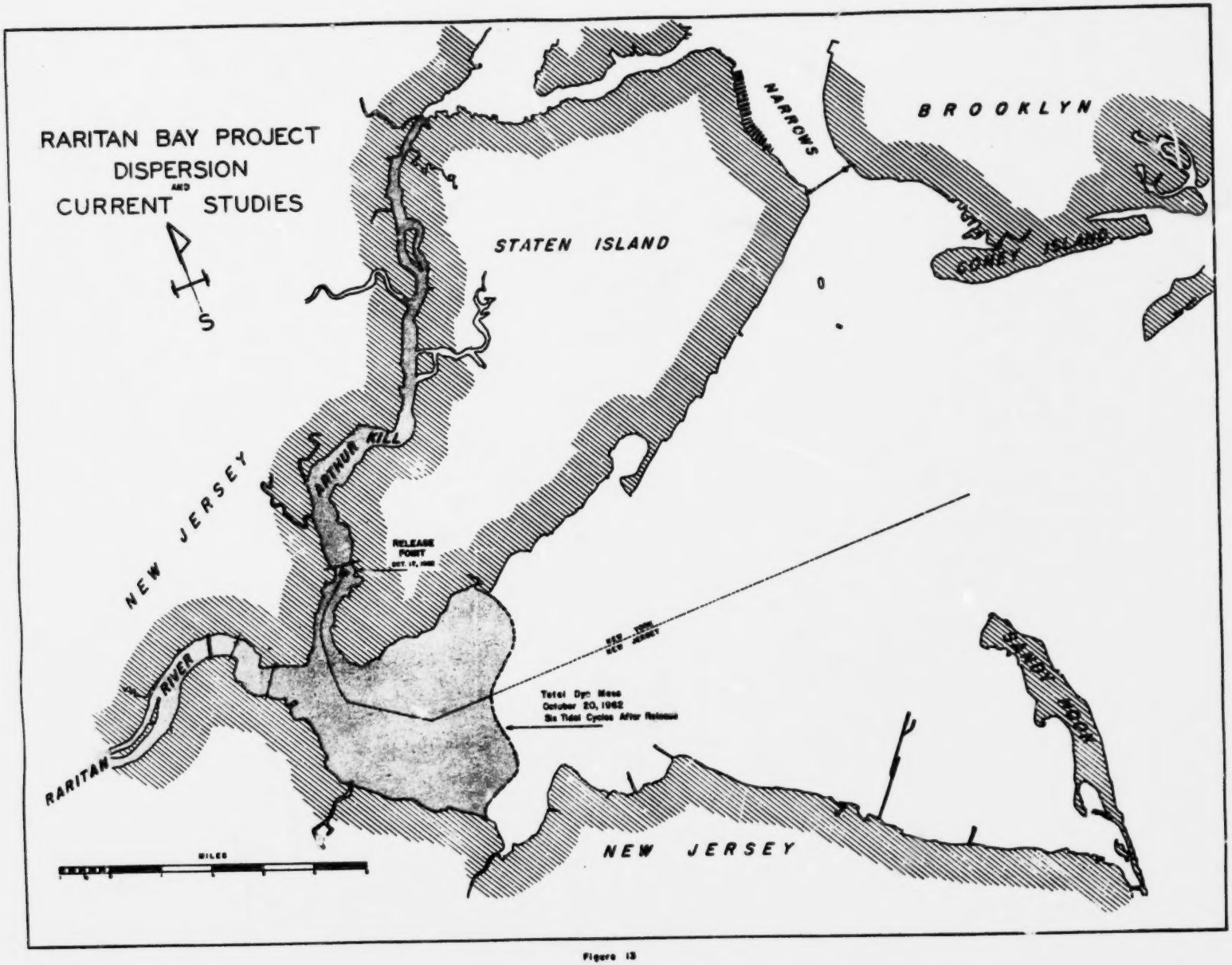
RARITAN BAY PROJECT
DISPERSION AND CURRENT STUDIES
N
S
NARROWS
BROOKLYN
STATEN ISLAND
CONEY ISLAND
ARTHUR KILL
NEW JERSEY
RELEASE POINT
RARITAN RIVER
Total Dye Mass
October 20, 1962
Six Tidal Cycles After Release
SANDY HOOK
NEW JERSEY
MILES

Figure 13

RARITAN BAY PROJECT

TABLE 2. SEWAGE TREATMENT PLANT PERFORMANCE

Frequency Distribution

TOTAL CHLORINE RESIDUALS milligrams per liter — Percent equal to or less than						SEWAGE TREATMENT PLANTS		CONFIRMED COLIFORM density per 100 milliliters — Percent equal to or greater than			
N	0.0	0.5	1.0	2.0	5.0			N	100	1000	10000
49	0	4	18	69	100	Oakwood Beach	24-hr	46	33	17	2
18	0	17	33	83	100		Spot	18	33	22	0
69	1	3	9	30	96	Perth Amboy	24-hr	69	16	3	1
30	3	17	33	67	100		Spot	30	63	37	10
78	12	41	73	90	100	Middlesex County	24-hr	71	42	34	13
18	11	39	72	83	100		Spot	17	47	24	12
62	10	24	32	58	100	South Amboy	24-hr	60	17	2	0
36	3	11	22	44	100		Spot	34	24	18	3
48	0	0	0	2	88	Keyport	24-hr	42	5	0	0
44	5	7	11	18	100		Spot	41	37	20	10
51	12	39	49	65	100	Keansburg	24-hr	45	67	33	9
40	0	10	28	75	100		Spot	42	52	33	17
51	18	29	33	49	82	Atlantic Highlands	24-hr	46	59	48	22
49	0	6	8	20	98		Spot	43	19	7	2
75	7	8	13	24	96	Highlands	24-hr	68	29	13	7
44	2	11	18	36	98		Spot	44	52	27	14

RARITAN BAY PROJECT

TABLE 3. SEWAGE TREATMENT PLANT DATA---24-HOUR SURVEYS JUNE - DEC 1962

Chemical Results

Plant	Date	Flow (MGD)	BIOCHEMICAL OXYGEN DEMAND Pounds per day Influent	Effluent	Percent Reduction	TOTAL SUSPENDED SOLIDS Pounds per day Influent	Effluent	Percent Reduction
Oakwood Beach	Aug 2	8.5	8,475[b]	3,504[b]		11,502	2,799	76
	Sep 27[a]	11.6	11,014	1,663	85	28,184	4,814	83
	Average	10.0	11,014	1,663	85	19,843	3,806	81
Perth Amboy	Jul 26	5.6	13,240	11,682	12			
	Sep 13	6.8	16,669	11,470	31	9,807	3,810	61
	Nov 8	5.7	7,825	7,509	4	11,829	3,900	67
	Average	6.0	12,578	10,220	19	10,818	3,855	64
Middlesex County	Aug 16	40.8	191,000	157,000	18	123,000	25,400	79
	Sep 20	40.0	221,000	185,000	16	121,000	28,200	77
	Nov 29	48.0	176,600	161,000	9	157,700	44,100	72
	Average	42.9	196,000	168,000	14	134,000	32,600	76
South Amboy	Sep 6	0.91	1,197	924	23	1,430	336	76
	Nov 15	0.88	1,284	1,005	22	1,150	301	74
	Average	0.90	1,240	964	22	1,290	318	75
Keyport	Nov 2	0.65	1,211	712	41	735	258	65
	Dec 13	0.76	1,021	678	34	600	220	63
	Average	0.70	1,116	695	38	668	239	64

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Rev.

RARITAN BAY PROJECT

TABLE 3. SEWAGE TREATMENT PLANT DATA---24-HOUR SURVEYS JUNE - DEC 1962 (Concl.)

Chemical Results

Plant	Date	Flow (MGD)	BIOCHEMICAL OXYGEN DEMAND Pounds per day Influent	Effluent	Percent Reduction	TOTAL SUSPENDED SOLIDS Pounds per day Influent	Effluent	Percent Reduction
Keansburg	Aug 30[a]	2.38	1,896	1,513	20	3,506	1,678	52
	Oct 25	1.44	1,071	688	36	966	688	29
	Average	1.91	1,483	1,100	26	2,236	1,183	47
Atlantic Highlands	Aug 23	0.79[d]	894	680	24	754	529	30
	Oct 11	0.79[d]	897	583	35	1,025	600	41
	Average	0.79	896	632	29	890	564	37
Highlands	Aug 9[a]	1.44[d]	868[c]	1,054[c]		2,911	1,648	43
	Oct 4[a]	1.44[d]	1,575	829	47	1,574	995	37
	Dec 6	0.55[d]	1,309	288	78	356	216	39
	Average	1.14	1,442	558	61	1,614	953	41

[a] Rain.

[b] BOD ran for 15 hours - 3:00 P.M. 8/2/62 to 6:00 A.M. 8/3/62 - not included in average.

[c] BOD ran for 17 hours - 1:40 P.M. 8/9/62 to 6:45 A.M. 8/10/62 - not included in average.

[d] Estimated.

oxygen conditions existing in the area of the junction of the Raritan River and Arthur Kill. Biochemical oxygen demand reductions at the Perth Amboy and Middlesex plants average 19% and 14% respectively. Considering the high suspended solids reduction accomplished by these two plants, it can be assumed that the majority of the biochemical oxygen demand is in the form of dissolved materials not ordinarily removable by primary treatment processes.

Rev.

Untreated Discharges

A survey of the untreated discharges to Raritan Bay was conducted. Two sources of raw discharges were found in the Raritan Bay area: toilet facilities on loading piers of the Earl Ammunition Depot, and seven outlets serving Tottenville, Staten Island.

The pier facilities of the Earl Ammunition Depot of the U. S. Navy (Leonardo, N. J.) serve work gangs which may, at peak operations, amount to approximately 300 men on an eight-hour shift. This situation has been discussed with the Engineering Officer, Third Naval District; his group is reviewing the engineering feasibility of using chemical toilets to solve this problem.

The second area of raw discharge is a series of seven outlets serving the Tottenville Area of Staten Island. The drainage area of each of these outlets was determined by field investigation. The estimated tributary population is about 3,000 persons.

Appropriate bacteriological tests revealed that samples obtained from the five largest outlets consist of raw sewage. Dye studies showed that these sewage flows (with the exception of one outlet) discharge to the waters of the bay.

RARITAN BAY PROJECT

TABLE A-1. SUMMARY OF BACTERIOLOGICAL DATA JUNE - DEC 1962

Bay Stations

Densities per 100 milliliters

Station	CONFIRMED COLIFORM N	CONFIRMED COLIFORM Geometric Mean	CONFIRMED COLIFORM Maximum	FECAL COLIFORM N	FECAL COLIFORM Geometric Mean	FECAL COLIFORM Maximum	FECAL STREPTOCOCCUS N	FECAL STREPTOCOCCUS Geometric Mean	FECAL STREPTOCOCCUS Maximum
1-S	20	73	350	18	27	240	25	49	45,000
1-D	20	77	920	19	37	350	16	39	3,900
2-S	20	76	1,600	17	29	350	17	86	7,300
2-D	19	51	920	16	27	540	24	99	50,000
3-S	20	160	3,500	17	55	1,700	24	71	250,000
3-D	19	170	3,500	16	75	1,700	17	100	140,000
4-S	20	560	16,000	17	38	5,400	17	51	15,000
4-D	19	540	9,200	17	290	9,200	21	170	51,000
5-S	17	1,200	9,200	14	380	5,400	22	170	160,000
5-D	18	1,600	16,000+	15	590	16,000	17	98	3,100
6-S	15	3,300	54,000	12	1,600	16,000+	16	120	4,200
6-D	16	4,600	35,000	13	1,300	35,000	21	340	100,000
7-S	17	3,100	16,000+	16	1,900	16,000+	20	160	4,000
7-D	17	3,600	16,000+	16	2,000	16,000	16	220	100,000
8-S	15	2,600	40,000	13	820	16,000	17	52	2,300
8-D	17	1,100	16,000+	15	460	9,200	22	240	15,000
9-S	17	1,300	17,000	14	830	11,000	22	130	5,000
9-D	15	660	5,400	14	250	4,900	17	78	2,600
10-S	16	2,400	16,000+	14	960	9,200	17	160	240,000
10-D	16	2,100	16,000+	14	790	16,000	21	250	350,000

RARITAN BAY PROJECT

TABLE A-1. SUMMARY OF BACTERIOLOGICAL DATA JUNE - DEC 1962 (Cont.)

Bay Stations

Densities per 100 milliliters

Station	CONFIRMED COLIFORM N	Geometric Mean	Maximum	FECAL COLIFORM N	Geometric Mean	Maximum	FECAL STREPTOCOCCUS N	Geometric Mean	Maximum
11-S	15	830	16,000+	11	590	3,500	21	300	140,000
11-D	15	840	16,000+	11	580	2,400	17	130	19,000
12-S	16	410	5,400	14	180	1,600+	17	49	51,000
12-D	16	580	9,200	13	160	1,600	21	70	87,000
13-S	15	100	920	12	46	920	20	74	150,000
13-D	15	100	540	12	45	350	17	150	130,000
14-S	15	42	1,600+	13	15	920	18	110	320,000
14-D	15	57	1,600+	13	21	920	20	61	7,700
15-S	13	44	1,800	10	11	130	19	48	40,000
15-D	13	35	920	9	12	540	15	120	90,000
16-S	13	26	1,600	12	13	350	14	56	45,000
16-D	13	39	540	12	20	350	19	140	20,000
17-S	15	240	2,400	12	130	1,600+	20	63	66,000
17-D	15	270	1,700	12	140	1,600+	16	38	12,000
18-S	15	360	3,500	12	210	2,400	15	22	14,000
18-D	15	660	9,200	12	290	3,500	18	100	60,000
19-S	14	1,000	16,000+	10	510	3,500	20	50	10,000
19-D	13	1,800	16,000	10	830	16,000	15	150	38,000
20-S	14	1,400	16,000+	11	690	5,400	16	170	2,200,000
20-D	15	2,600	17,000	11	860	16,000	20	160	39,000

RARITAN BAY PROJECT

TABLE A-1. SUMMARY OF BACTERIOLOGICAL DATA JUNE - DEC 1962 (Cont.)

Bay Stations

Densities per 100 milliliters

Station	CONFIRMED COLIFORM N	Geometric Mean	Maximum	FECAL COLIFORM N	Geometric Mean	Maximum	FECAL STREPTOCOCCUS N	Geometric Mean	Maximum
21-S	13	870	16,000+	11	350	5,400	17	75	150,000
21-D	13	1,600	16,000	11	560	5,400	14	250	61,000
22-S	14	930	16,000+	12	400	3,500	16	85	35,000
22-D	14	1,300	9,200	11	500	3,500	18	100	43,000
23-S	12	380	9,200	7	380	9,200	17	34	12,000
23-D	12	640	16,000	7	420	5,400	14	280	110,000
24-S	13	110	1,600+	12	74	1,600+	15	53	23,000
24-D	13	250	1,600+	12	140	1,600	17	35	4,000
25-S	13	220	1,600+	11	210	1,600+	18	35	20,000
25-D	13	500	2,200	10	290	1,600+	16	56	9,800
26-S	12	300	1,700	10	190	1,600+	14	19	3,300
26-D	12	760	5,400	9	390	3,500	16	64	7,600
27-S	12	160	3,500	8	40	540	17	37	7,000
27-D	12	280	2,400	8	66	790	15	35	2,700
28-S	13	130	540	9	95	540	14	30	2,000
28-D	13	130	1,600	9	110	920	17	80	4,800
29-S	13	43	540	9	16	140	17	58	60,000
29-D	13	71	540	9	25	170	14	24	200
30-S	16	81	1,600	12	39	540	15	64	3,800
30-D	16	99	540	13	25	350	20	76	1,900

RARITAN BAY PROJECT

TABLE A-1. SUMMARY OF BACTERIOLOGICAL DATA JUNE - DEC 1962 (Cont.)

Bay Stations

Densities per 100 milliliters

Station	CONFIRMED COLIFORM N	Geometric Mean	Maximum	FECAL COLIFORM N	Geometric Mean	Maximum	FECAL STREPTOCOCCUS N	Geometric Mean	Maximum
31-S	16	160	1,600+	13	66	1,600	20	29	940
31-D	16	110	920	12	40	540	15	27	260
32-S	17	500	9,200	13	170	9,200	14	58	45,000
32-D	17	360	16,000+	13	100	1,600	20	130	83,000
33-S	18	2,000	16,000+	13	540	9,200	20	87	3,000
33-D	17	710	16,000	12	290	16,000	17	67	45,000
34-S	17	1,400	16,000	13	740	16,000	15	79	31,000
34-D	17	1,200	24,000	13	480	1,600+	18	85	2,300
463-S	16	9,000	54,000	11	2,400	35,000	18	140	1,300
463-D	15	7,200	17,000	10	3,100	16,000	13	360	230,000
*45-S	5	67	240	5	13	49	6	88	48,000
46-S	4	71	1,100	4	20	490	5	37	200
47-S	5	59	350	5	14	170	6	78	25,000
48-S	4	36	79	4	12	49	5	28	160
49-S	2	22		2	7		3	78	
50-S	2	47		2	16		3	190	
51-S	2	47		2	8		3	360	
52-S	5	55	1,600	5	9	280	5	120	300
53-S	2	22		2	3		3	140	
54-S	5	140	350	5	16	130	5	1,300	42,000

RARITAN BAY PROJECT

TABLE A-1. SUMMARY OF BACTERIOLOGICAL DATA JUNE - DEC 1962 (Concl.)

Bay Stations

Densities per 100 milliliters

Station	CONFIRMED COLIFORM N	CONFIRMED COLIFORM Geometric Mean	CONFIRMED COLIFORM Maximum	FECAL COLIFORM N	FECAL COLIFORM Geometric Mean	FECAL COLIFORM Maximum	FECAL STREPTOCOCCUS N	FECAL STREPTOCOCCUS Geometric Mean	FECAL STREPTOCOCCUS Maximum
55-S	5	460	2,200	5	57	1,100	5	690	8,000
56-S	3	200		3	49		3	2,000	
58-S	5	610	16,000	5	36	120	6	1,200	220,000
59-S	5	440	1,600+	5	49	1,600+	4	470	15,000
60-S	5	2,500	16,000+	5	120	1,600+	5	510	100,000
61-S	3	2,800		3	1,100		3	1,800	
62-S	5	10,000	35,000	5	1,500	22,000	5	1,900	2,000
64-S	5	3,700	35,000	6	250	490	6	4,000	170,000
65-S	6	3,100	92,000	6	240	350	7	240	1,600

*Stations 45 to 65 sampled Oct - Dec 1962.

RARITAN BAY PROJECT

TABLE A-2. SUMMARY OF BACTERIOLOGICAL DATA JUNE - DEC 1962

Shore Stations

Densities per 100 milliliters

Station	CONFIRMED COLIFORM N	Geometric Mean	Maximum	FECAL COLIFORM N	Geometric Mean	Maximum	FECAL STREPTOCOCCUS N	Geometric Mean	Maximum
				New Jersey					
701	20	55	920	10	25	130	24	28	15,000
702	19	240	1,700	12	48	790	26	68	11,000
703	18	96	1,300	11	36	350	26	44	500
704	19	190	9,200	13	69	3,500	27	93	28,000
705	21	140	3,500	11	22	140	28	170	26,000
706	21	420	9,200	14	120	2,400	27	130	4,100
707	21	310	16,000+	13	47	490	28	100	5,600
708	20	470	16,000+	13	49	490	27	95	8,300
709	16	320	1,700	9	96	790	24	180	12,000
710	20	420	16,000+	15	72	490	28	280	72,000
711	15	280	9,200	8	120	1,300	21	120	3,900
712	15	190	1,600+	10	50	540	22	340	8,000
713	10	480	16,000	7	160	3,500	17	740	240,000
714	8	320	1,600+	7	140	920	16	600	260,000
715	6	500	1,600+	6	200	1,600+	12	120	25,000
716	7	1,300	1,600+	6	1,200	1,600+	12	310	2,200

RARITAN BAY PROJECT

TABLE A-2. SUMMARY OF BACTERIOLOGICAL DATA JUNE - DEC 1962 (Concl.)

Shore Stations

Densities per 100 milliliters

Station	CONFIRMED COLIFORM N	CONFIRMED COLIFORM Geometric Mean	CONFIRMED COLIFORM Maximum	FECAL COLIFORM N	FECAL COLIFORM Geometric Mean	FECAL COLIFORM Maximum	FECAL STREPTOCOCCUS N	FECAL STREPTOCOCCUS Geometric Mean	FECAL STREPTOCOCCUS Maximum
New York									
601	21	3,900	160,000	14	620	54,000	27	260	4,100
602	21	2,500	70,000	16	720	54,000	27	140	28,000
603	20	1,300	54,000	13	260	4,900	26	56	1,200
604	20	1,700	16,000+	17	560	4,600	26	46	5,500
605	19	650	3,500	13	190	920	26	48	9,000
606	20	380	2,200	16	140	1,600	27	68	700
607	19	340	1,600	12	95	490	24	110	688,000
608	21	380	16,000	16	150	9,200	26	120	3,200
609	17	160	790	11	46	350	23	100	35,000
610	13	140	1,600+	9	36	1,600+	18	150	190,000
611	14	380	5,400	9	86	460	20	92	2,400
612	16	390	9,200	11	190	3,500	22	140	4,000
613	16	320	16,000	13	140	16,000	21	360	4,600
614	9	270	1,600+	8	160	1,600+	14	67	8,600
615	8	370	2,200	7	140	1,600+	13	430	11,000
616	7	710	7,900	7	210	2,200	12	990	56,000
617	5	690	1,600+	5	250	1,600+	9	400	13,000

RARITAN BAY PROJECT

TABLE A-3. SUMMARY OF CHEMICAL DATA JUNE - DEC 1962

Bay Stations

Station	N	Average Temp °C	Average Chloride (mg/l)	DISSOLVED OXYGEN mg/l Average	mg/l Minimum	Percent Saturation Average	Percent Saturation Minimum
1-S	26	17.2	13900	6.76	4.10	80	53
1-D	26	17.2	14000	6.31	4.30	74	53
2-S	26	17.1	13900	6.50	4.73	81	59
2-D	26	17.1	14000	7.78	4.48	80	58
3-S	25	17.0	14000	6.88	4.60	81	54
3-D	26	17.0	14100	6.67	4.60	78	54
4-S	25	17.0	14100	6.62	4.50	78	53
4-D	26	16.9	14200	6.44	4.50	75	53
5-S	24	16.8	14100	6.17	4.00	73	53
5-D	24	16.8	14300	5.96	4.30	69	50
6-S	22	17.4	14200	6.02	4.10	71	47
6-D	22	17.1	14400	6.03	4.10	70	49
7-S	22	17.4	14200	5.89	3.64	69	46
7-D	23	17.3	14600	5.92	4.18	70	53
8-S	23	17.1	14400	6.13	3.11	72	42
8-D	23	16.6	15400	6.43	4.23	77	55
9-S	23	17.1	14700	6.24	3.58	73	48
9-D	23	17.0	15400	6.27	4.42	74	58
10-S	23	17.3	14300	6.23	3.24	74	42
10-D	23	17.0	14800	6.02	3.71	71	48

RARITAN BAY PROJECT

TABLE A-3. SUMMARY OF CHEMICAL DATA JUNE - DEC 1962 (Cont.)

Bay Stations

Station	N	Average Temp °C	Average Chloride (mg/l)	DISSOLVED OXYGEN mg/l Average	DISSOLVED OXYGEN mg/l Minimum	DISSOLVED OXYGEN Percent Saturation Average	DISSOLVED OXYGEN Percent Saturation Minimum
11-S	20	17.7	14600	6.41	4.19	77	56
11-D	20	17.7	14700	6.23	4.06	74	52
12-S	20	17.9	14400	7.02	5.15	84	63
12-D	20	18.0	14700	6.83	5.13	83	63
13-S	20	18.0	14500	7.60	5.90	92	75
13-D	20	17.9	14800	7.26	5.80	87	66
14-S	20	18.1	14300	7.79	5.80	100	69
14-D	20	17.9	14300	7.04	4.80	84	62
15-S	20	17.6	12900	8.81	5.60	106	66
15-D	20	17.8	13900	7.85	5.30	94	62
16-S	19	17.6	13900	8.51	5.60	102	66
16-D	19	17.3	14200	7.14	4.20	84	53
17-S	21	18.0	14200	7.77	5.60	94	68
17-D	21	17.8	14600	7.03	5.10	84	60
18-S	20	17.8	13500	7.48	5.00	90	60
18-D	20	17.6	14500	6.53	4.95	78	61
19-S	19	17.3	14100	6.77	4.63	80	57
19-D	19	17.3	14500	6.34	4.77	75	57
20-S	20	17.4	14100	6.35	4.26	74	52
20-D	20	17.5	14200	6.09	3.69	41	47

RARITAN BAY PROJECT

TABLE A-3. SUMMARY OF CHEMICAL DATA JUNE - DEC 1962 (Cont.)

Bay Stations

Station	N	Average Temp °C	Average Chloride (mg/l)	DISSOLVED OXYGEN mg/l Average	mg/l Minimum	Percent Saturation Average	Percent Saturation Minimum
21-S	18	18.6	14200	6.30	4.10	77	52
21-D	18	18.3	14200	5.69	4.31	71	55
22-S	18	19.0	14100	7.17	4.80	88	58
22-D	18	18.7	14400	6.37	4.50	74	54
23-S	17	18.6	14100	7.64	5.50	93	65
23-D	17	18.3	14300	6.26	4.60	75	55
24-S	16	19.1	14100	8.27	5.50	104	64
24-D	17	18.7	14500	6.41	5.30	78	63
25-S	17	19.0	14000	8.07	4.20	100	53
25-D	17	18.7	14200	6.27	4.60	76	56
26-S	17	18.6	14100	7.59	5.17	94	63
26-D	17	18.4	14200	6.39	4.80	76	57
27-S	17	18.9	14100	8.19	5.50	102	66
27-D	17	18.6	14200	5.84	4.70	80	56
28-S	18	19.3	14000	7.65	5.30	95	61
28-D	18	18.8	14100	6.83	4.90	84	60
29-S	18	19.2	14000	7.26	2.30	90	29
29-D	18	18.9	14000	6.36	2.40	78	30
30-S	20	17.3	13700	7.02	3.00	82	35
30-D	20	17.1	13900	6.48	3.50	75	44

RARITAN BAY PROJECT

TABLE A-3. SUMMARY OF CHEMICAL DATA JUNE - DEC 1962 (Cont.)

Bay Stations

Station	N	Average Temp °C	Average Chloride (mg/l)	DISSOLVED OXYGEN mg/l Average	mg/l Minimum	Percent Saturation Average	Percent Saturation Minimum
31-S	21	17.4	13600	7.08	4.40	84	53
31-D	21	17.1	13900	6.44	4.10	75	52
32-S	21	17.9	13200	6.42	3.50	76	42
32-D	21	17.6	13700	5.81	4.10	68	49
33-S	21	18.0	13000	5.63	2.50	66	32
33-D	21	17.7	13200	5.48	3.30	64	40
34-S	21	18.2	13000	5.43	2.90	65	34
34-D	21	17.9	12500	5.19	2.40	61	30
463-S	17	16.9	11200	5.28	2.20	59	28
463-D	17	17.1	12200	4.97	2.00	55	25
*45-S	6	12.3	13000	6.25	4.50	65	50
46-S	5	11.6	13000	6.68	4.90	68	58
47-S	6	12.3	13600	6.92	4.95	73	60
48-S	5	12.2	13300	7.37	5.70	78	67
49-S	3	8.3	13100	8.22		81	
50-S	3	8.8	13300	8.37		83	
51-S	3	8.5	13200	8.60		85	
52-S	6	12.1	12600	7.22	5.40	76	63
53-S	3	9.1	12300	8.10		81	
54-S	6	11.9	12300	6.30	3.57	65	43

RARITAN BAY PROJECT

TABLE A-3. SUMMARY OF CHEMICAL DATA JUNE - DEC 1962 (Concl.)

Bay Stations

Station	N	Average Temp °C	Average Chloride (mg/l)	DISSOLVED OXYGEN mg/l Average	DISSOLVED OXYGEN mg/l Minimum	DISSOLVED OXYGEN Percent Saturation Average	DISSOLVED OXYGEN Percent Saturation Minimum
55-S	5	13.0	12300	5.78	3.33	60	40
56-S	5	8.2	12700	7.06	4.30	68	48
58-S	6	9.8	12800	6.37	3.95	63	44
59-S	5	13.0	12000	5.35	3.52	56	42
60-S	5	13.1	12200	4.69	2.60	49	32
61-S	4	9.6	11000	5.89	4.20	58	47
62-S	4	14.6	12700	4.25	2.40	45	27
64-S	7	11.6	12000	5.42	2.90	53	35
65-S	7	11.3	12000	5.37	3.00	54	36

* Stations 45 to 65 sampled Oct - Dec 1962.

RARITAN BAY PROJECT

TABLE A-4. SUMMARY OF BACTERIOLOGICAL DATA JUNE - DEC 1962

Entrant Waters to the Bay

Densities per 100 milliliters

Station	CONFIRMED COLIFORM N	CONFIRMED COLIFORM Geometric Mean	CONFIRMED COLIFORM Maximum	FECAL COLIFORM N	FECAL COLIFORM Geometric Mean	FECAL COLIFORM Maximum	FECAL STREPTOCOCCUS N	FECAL STREPTOCOCCUS Geometric Mean	FECAL STREPTOCOCCUS Maximum
100-S	7	27,000	32,000	6	9,700	24,000	5	670	7,700
100-D	7	9,600	35,000	6	5,400	24,000	4	670	3,400
101-S	9	30,000	92,000	9	6,000	24,000	11	2,600	39,000
101-D	9	16,000	92,000	9	3,900	22,000	11	660	27,000
102-S	7	19,000	35,000	7	6,600	16,000+	9	680	2,100
102-D	7	12,000	35,000	7	5,100	16,000	8	530	4,000
103-S	9	27,000	160,000	9	8,900	54,000	10	950	230,000
103-D	9	20,000	54,000	9	3,300	13,000	11	600	34,000
104-S	7	14,000	54,000	5	5,000	11,000	5	1,600	2,500
104-D	7	13,000	22,000	5	4,900	13,000	4	830	1,100
123-S	27	1,300	24,000	21	380	2,200	29	50	18,000
123-D	28	830	5,400	22	260	1,600	28	79	300,000
066-S	10	740	5,400	10	190	3,500	36	60	690
067-S	10	910	16,000	10	210	5,400	36	81	1,300

RARITAN BAY PROJECT

TABLE A-5. SUMMARY OF CHEMICAL DATA JUNE - DEC 1962

Entrant Waters to the Bay

Station	N	Average Temp °C	Average Chloride (mg/l)	DISSOLVED OXYGEN mg/l Average	mg/l Minimum	Percent Saturation Average	Percent Saturation Minimum
100-S	7	10.7	14700	5.90	5.10	62	52
100-D	7	10.4	16500	6.00	5.00	64	50
101-S	14	14.6	14300	5.21	3.70	58	48
101-D	14	14.2	14900	8.71	4.32	68	57
103-S	14	14.4	13600	5.25	3.50	58	46
103-D	14	14.3	14800	5.71	3.80	64	50
104-S	7	10.1	13300	5.43	4.30	56	46
104-D	7	10.5	14500	5.86	4.60	61	50
123-S	12	19.8	10800	4.33	2.65	50	27
123-D	12	19.5	12300	3.83	3.45	46	23

RARITAN BAY PROJECT

TABLE A-6. SUMMARY OF BACTERIOLOGICAL DATA JUNE - DEC 1962

Sewage Treatment Plants

Densities per 100 milliliters

Sewage Treatment Plant		CONFIRMED COLIFORM MPN N	Geometric Mean	Maximum	FECAL COLIFORM MPN N	Geometric Mean	Maximum	MF STREPTOCOCCUS N	Geometric Mean	Maximum
Oakwood Beach	Inf	56	15,000,000	920,000,000	30	4,500,000	32,000,000	64	1,100,000	27,000,000
	Eff	64	49	9,200	38	6	1,600	73	48	70,000
Perth Amboy	Inf	79	35,000,000	54,000,000	73	850,000	8,000,000	71	1,300,000	110,000,000
	Eff	99	35	16,000+	93	9	5,400	79	450	300,000
Middlesex County	Inf	81	15,000,000	220,000,000	77	1,200,000	160,000,000	73	7,200,000	2,000,000,000
	Eff	88	120	16,000,000+	83	9	1,600+	80	43	340,000
South Amboy	Inf	70	8,600,000	240,000,000	62	2,500,000	63,000,000	65	1,900,000	78,000,000
	Eff	84	32	16,000+	80	6	1,090	72	51	770,000
Keyport	Inf	54	2,200,000	350,000,000	51	660,000	220,000,000	37	720,000	35,000,000
	Eff	83	13	16,000+	81	5	16,000+	44	82	66,000
Keansburg	Inf	60	4,600,000	54,000,000	52	1,400,000	13,000,000	54	370,000	50,000,000
	Eff	67	930	16,000+	80	30	16,000+	58	21	250,000
Atlantic Highlands	Inf	59	400,000	350,000	55	72,000	70,000,000	68	800,000	36,000,000
	Eff	89	72	160,000+	86	11	160,000+	75	63	1,700,000,000
Highlands	Inf	80	13,000,000	160,000,000	72	4,500,000	350,000,000	89	1,400,000	46,000,000
	Eff	112	60	16,000+	106	17	16,000+	83	95	940,000

METHODOLOGY

Station Locations

A sampling program for the waters of Raritan Bay and its tributary streams and sewage treatment plant effluents was based on an extensive review of data collected, through 1961, by state and interstate agencies in the area.

The network of Project sampling stations was designed to (1) characterize the gradient of water quality within the bay and (2) make maximum use of existing information. There is a station for approximately every two square miles of water area; station designations and coordinate locations are shown in Table B-1. This table also indicates those stations sampled regularly by state and interstate agencies.

A series of stations along the shores of Staten Island and New Jersey were used to characterize the quality of waters in and along the shorelines. The shoreline stations on Staten Island largely duplicate those sampled by the New York City Department of Health.

Sampling Schedule

Frequency of sampling is as important as the location of stations. Changes in water quality characteristics in relation to time were analyzed from previously accumulated data; this data suggested that long term or seasonal characteristics have the more important effects on water quality (because of the averaging effects of the tidal embayment).

Therefore, the program was designed to provide consecutive, equally-spaced samples over a period of one year--at intervals of approximately one week. This program consisted of weekly (Tuesday) samplings of: 54 bay stations at surface; 35 bay stations at bottom depth; 33 shoreline stations at surface; 8 major sewage treatment plants. Certain practical limitations (e.g. weather problems, mechanical failure of boats) forced occasional adjustment of this schedule to Monday or Wednesday. This program has been maintained since June 1962.

Other sampling is conducted to determine short term variations in water quality. Each major treatment plant has been sampled hourly over a 24-hour period on two or more occasions. Cross-sections of various entrant streams (including the Narrows, Arthur Kill and Raritan River) have been studied for periods of six or more hours.

Sampling Methods

Bay Stations: Surface samples of bay water are collected five

feet below the water surface; deep samples are collected five feet above the bottom--using a Kemmerer water bottle (standard oceanographic sampling unit for estuarial work). The Kemmerer bottle contains approximately 2,200 ml of sample collected at a prescribed depth by a messenger-actuated closure device.

The sample is drawn from the bottle, by means of a rubber tube and valve arrangement, into various sampling containers for specific analytical purposes. The first portion of the sample is used to measure dissolved oxygen; the second portion to measure temperature and conductivity; the third portion (approximately mid-volume of the sampling container) to determine bacteriological quality; the last portion is used for various other analyses as may be required.

Dissolved oxygen samples are fixed and titrated aboard the sampling vessel within about 30 minutes of collection. Bacteriological samples are plated or planted within about ten minutes of collection. All MPN tubes and membrane filters--after innoculation aboard the sampling vessel--are returned to the laboratory within a maximum time of six hours for incubation, counting and further differentiation.

Temperature and conductivity measurements are made aboard the sampling vessel immediately upon collection of the samples.

Analyses for biochemical oxygen demand (or other specific constituents) are made upon iced or fixed samples as the procedures in Standard Methods prescribe; this is done after return of the samples to the laboratory.

Shore Stations: At all shore stations, sampling procedures are carried to completion in station wagons equipped to operate as small field laboratories. Shoreline samples are collected in four-ounce ground-glass-stoppered sterile containers; the samples are collected from the surf by wading out to points approximately two feet deep. Time of planting and analyses schedules are the same as aboard the boats.

Treatment Plants: Sampling procedures at the treatment plants closely parallel methods used in the bay and on the shores. There is one exception: bacteriological samples of chlorinated effluents are held in the chlorinated state for a period of time equivalent to the time plant effluents require to pass from the point of collection to the point of entrance into bay waters. After this time interval the samples are dechlorinated.

The holding time is estimated on basis of the flow and hydraulic characteristics of the treatment plant contact chamber and outfall. In any case, samples are not held longer than 30 minutes. Dechlorination is accomplished by addition of sterile thiosulfate solution.

RARITAN BAY PROJECT

TABLE B-1. LOCATION OF SAMPLING STATIONS

Shore Line

PHS Number		N.Y.C. Health Dept.
	New York Shore	
601	South Beach, Field 5, Lane 1, foot Sand Lane	75
602	South Beach, Field 4, Lane 8, by 445 Seaside Blvd.	79
603	South Beach, by 517 Seaside Blvd., Parking Gate 4	79A & SB-1
604	South Beach, foot Seaview Ave, end of fence	
605	South Beach, foot Lincoln Ave, Section A, Lane 1	81
606	New Dorp Beach, foot New Dorp Lane	83
607	Foot Fox Lane	
608	Great Kills Park, north of bath house	PD-2
609	Great Kills Park, Crookes Point, rock jetty	CP-1
610	Great Kills Yacht Club	GKH-1
611	Annadale Beach, foot Lipsett Ave	85
612	Huguenot Beach, foot Huguenot Ave	87
613	Wolf Pond Park	90
614	Princess Bay, foot Sequine Ave	91
615	Mt. Loretto, front of bath houses	138
616	Tottenville, foot Manhattan St.	139
617	Tottenville, foot Hylan Blvd.	
	New Jersey Shore	
701	Highlands, Shrewsbury River Bridge on Route 36	
702	Highlands, Water Witch Beach, foot Central Ave	
703	Atlantic Highlands, foot First Ave	
704	Leonardo, Conover Beach, foot Leonardo Ave	
705	Port Monmouth, E. Kay's Beach, 1/2 mile W. Wilson Ave	
706	E. Keansburg, Ideal Beach, foot Hudson Ave	
707	Keansburg, Main Street Beach, foot Maint St.	
708	Keansburg, Beach, Grandview and Beachway	
709	Keansburg, Belvedere Beach, foot Oakwood Place	
710	Raritan, Union Beach, Florence Ave and Front St.	
711	Keyport Beach, foot Cedar St.	
712	Cliffwood Beach, foot Lakeshore Dr.	
713	Madison Township Recreation Area	
714	Morgan Beach, foot Cliffwood Way	
715	Morgan, West side Cheesequake Creek	
716	Perth Amboy Beach, foot State Street	
	Sewage Treatment Plants	
803	Oakwood Beach Pollution Control Plant	
842	Perth Amboy Sewage Treatment Plant	
854	Middlesex County Sewerage Authority	
860	South Amboy Sewage Treatment Plant	
875	Keyport Sewage Treatment Plant	
878	Keansburg Sewage Treatment Plant	
884	Atlantic Highlands Sewage Treatment Plant	
887	Highlands Sewage Treatment Plant	

TABLE B-1. LOCATION OF SAMPLING STATIONS (Cont.)

Bay Waters

P.H.S. CODE	74° LONGITUDE MIN	SEC	40° LATITUDE MIN	SEC	OTHER AGENCY CODE NUMBER NEW YORK CON. DEPT.	NEW JERSEY HEALTH DEPT.	I.S.C.
Bay Stations							
1	9	52	30	14	39		
2	8	38	30	27	59		
3	7	21	30	41	57		
4	6	6	30	54	9		
5	5	17	32	3	81		
6	4	5	32	17	86		
7	2	43	32	30	90		
8	1	37	32	40			
9	1	13	31	45			
10	2	27	31	32	92		
11	2	8	30	34	94	3	
12	1	52	29	37		12	
13	1	34	28	39		78	
14	1	17	27	42			
15	0	59	26	44			
16	2	19	26	30		101	
17	2	54	28	25		80	
18	3	11	29	23		45	
19	3	28	30	20	88	5	
20	3	45	31	18	87		
21	5	2	31	4	82		
22	4	44	30	7	83	7	
23	4	27	29	10		47	
24	4	10	28	12		82	
25	5	32	28	58		49A	
26	5	49	29	56	11	8A	
27	7	5	29	44	13	10	
28	8	20	29	31	15	11A	
29	9	36	29	18	17	13	
30	11	18	30	32	38		
31	12	26	30	20	36A		
32	13	45	29	28	34		
33	15	2	29	29	26		
34	15	32	30	6			18

RARITAN BAY PROJECT

TABLE B-1. LOCATION OF SAMPLING STATIONS (Concl.)

Bay Waters

P.H.S. CODE	74° LONGITUDE MIN	SEC	40° LATITUDE MIN	SEC	OTHER AGENCY CODE NUMBER NEW YORK CON. DEPT.	NEW JERSEY HEALTH DEPT.	I.S.C.
45	10	53	29	5	19	14A	
46	9	20	28	21		53	
47	8	4	28	34		51A	
48	6	54	28	45		50	
49	5	14	28	2		83A	
50	3	52	27	15		97A	
51	4	56	28	5		97B	
52	6	30	27	49		85	
53	9	3	27	25		63A	
54	10	35	28	7		54A	
55	11	45	27	57		56	
56	12	0	28	54	21	16	
58	13	30	28	38	23	18	
59	13	11	27	41		58	
60	14	46	28	27			
61	14	55	29	7	30	20A	
62	16	10	29	23			
64	15	12	28	52			1-6
65	15	12	28	52			1-6
Bay Entrance Stations							
					Arthur Kill		
66	15	40	30	20			
67	15	24	30	44			
					Narrows		
100	2	25	36	35			
101	2	36	36	31			
102	2	47	36	28			
103	2	58	36	24			
104	3	10	36	21			
					Raritan River		
463	16	59	29	49			

Temperature and pH measurements are made on collection. Iced samples are returned to the laboratory for analysis for suspended solids (volatile and fixed), and for biochemical oxygen demand.

Laboratory Procedures

In chemical and bacteriological determinations, the procedures recommended by the 11th Edition of Standard Methods for the Examination of Water and Wastewater were followed whenever applicable.

Coliforms were determined by the multiple tube procedure; an additional test for the confirmation of coliforms (utilizing an elevated temperature of 44.5°C.) was added for the identification of the fecal coliforms present.

The streptococcal group was also determined routinely, using KF media by membrane filter procedure. The validity of these counts was confirmed by adequate comparison of split samples, using both KF and M-Enterococcus Media, followed by the identification of random colony picks from positive plates.

Chlorides were determined by using the mercuric nitrate procedure; confirmation was with a salinometer calibrated for sea water.

Biochemical oxygen demand was determined by the standard five-day, 20°C., incubation in a covered water bath.

All pH measurements were made in the field, using a portable pH meter standardized with standard buffer solution at regular intervals in the field.

Thermometers used for measuring temperatures were standard mercury glass thermometers, calibrated to 1/10°C.

BIOLOGICAL STUDIES

Introduction. Industrial and domestic discharges into Raritan Bay and adjacent waters impose another factor on the already complex assay of the natural environment. The evaluation of the effect of these discharges on the biology of the bay[1], exclusive of the natural ecology, is difficult. The history of shellfish, the former economic resource of the bay, is well documented with evidence which relates its decline to both manmade and natural causes (Nelson, 1960). For the present at least, the harvesting of shellfish is prohibited. Unfortunately, there are no inclusive histories of other organisms to compare past populations with the present. Jeffries (1959) and Patten (1959) studied the plankton during the years 1957-1959, but their stations did not exceed the outer limits of a line from Great Kills to Point Comfort. Dean (unpublished data) conducted benthic surveys of the bay from 1956-1960. His sampling was limited to only short summer periods.

The present objectives of the biological program for this project are to describe qualitatively and quantitatively the biological populations of the bay, and to relate existing natural and manmade environmental effects where possible. To carry out the aim of this project, a survey of the biological populations is being conducted of both the plankton and the benthos. Samples are examined with respect to kinds, numbers, associations and changes thereof. Although lagging behind the advances made in fresh-water biology, there are accepted pollution tolerant organisms and community structures which differentiate polluted from non-polluted brackish waters (Braarud 1955, Gilet 1960, Hartman 1960, Hood 1958 1960, McKnulty et. al. 1959, Mohr 1959, Reish 1957 1960, Zo Bell 1960 and others). However, because the effects of natural causes cannot be entirely separated, the use of laboratory experimentation becomes imperative.

Field Methods. Initially, six sampling stations (I-VI) were selected (Figure 12, Main Report). Choice was based upon previous studies (New Jersey-New York 1961, Jeffries 1962) and personal observations and communications. Samples were collected at approximately two week intervals. Sampling time did not exceed eight hours.

Phytoplankton. Water samples for subsequent phytoplankton analysis were taken at a 2-foot depth with a Kemmerer bottle. Two one liter amber bottles were filled and placed in the shade. One was kept under refrigeration overnight for analysis the next day. The other was used the same day for chlorophyll determination.

1-Bay - to include both Raritan Bay, Lower New York Bay and adjacent waters, unless specified otherwise.

A net sample was taken by towing a five inch diameter #20 net at slow speed for three minutes. The collected material was preserved in 5% formalin.

Benthos. Bottom samples were obtained employing a Petterson Dredge. The dredgings were placed in a large enamel tray. Odor, color, stratification and other observations were noted. After mixing, a one quart portion was preserved in 10% formalin for laboratory analysis.

Temperature. Surface temperatures were obtained from a bucket thermometer. A reversing thermometer was used for bottom temperatures. Bottom sediment temperatures were estimated by inserting a thermometer into the sediment immediately upon emptying the dredge. A battery operated field meter was used for measuring pH.

Light and Salinity. Light penetration was estimated with a Secchi disc. Salinity values were read directly by inserting the probe of a salinometer (corrected for temperature) into a bucket of sampled water.

Laboratory Analysis. Qualitative and quantitative estimates of phytoplankton were evaluated by counting in a Sedgwick-Rafter chamber. Taxonomy was determined from the net samples. Mr. A. Bleeker, Botany Dept., Rutgers University, obtained chlorophyll a values after the method of Richards with Thompson (1952).

Bottom materials were washed through eight inch diameter #4, #18 and #30 screens. The organisms were then washed into trays, picked out and sorted. Under low magnification, types, numbers and volumes of benthos were estimated.

Results - Phytoplankton - Species Composition and Seasonal Variation. Two separate patterns of phytoplankton community composition developed during the sampling period from September to December. Generally, flagellates dominated the flora in the late summer and early fall (Table B-2). Late fall began with two dominants, diatoms and greens, but diatoms later predominated. Between the two periods, composition was not distinctive to any one group. Protozoa occurred at all stations throughout the sampling period (Table B-2).

Peridinium trochoideum, a dinoflagellate, characterized the early pattern by being dominant at all stations except II and III (Table B-3). At these stations Skeletonema costatum, a diatom, was dominant. In the late fall, S. costatum, Coscinodiscus subtilis, and Nannochloris atomus, diatoms and a green algae predominated.

The phytoplankton populations were mainly characterized by

diatoms (Table B-3) yet flagellates and greens stand out at certain periods. From Table B-2, it is noted that more diatom species are found at the outer stations (II and III) than at the inshore stations (I, IV, V, VI). Station II appeared as having the most varied composition, while Station I varied the least. However, at this station dominance was shared by the greatest variation of different organisms. Station IV had the smallest variability among dominants.

On September 20, a distinct band of red water was observed approximately one mile off shore from Pt. Comofrt. This band, about 150-200 yards wide, ran NW-SE for approximately one-half mile, then curved rather sharply to the west and ran out of sight. The sharp delineation of the band from the surrounding water was emphasized by Secchi disc readings; inside the band the reading was 4.8 feet and less than three feet away the reading was 7.0 feet. The organism present which gave the water a red color was tentatively identified as a species of Goniaulax, a dinoflagellate. Members of this genus have been associated with "fish-kills" elsewhere. Patten (1961) observed red tides in the bay, but they were characterized by Massarita rotundata, a flagellate.

Abundance in Temporal and Spatial Distribution. Figures B-1 - B-6 give concentrations of phytoplankton cells/ml. Counts ranged from 10-843 cells/ml. Generally, there was a greater abundance in late summar, a sharp decline during October, and a rise at all stations in late fall. Station I exhibited the greatest abundance overall, while Station IV contained the fewest numbers. Greater fluctuations in numbers occurred at Station VI than at any other station (Figures B-1 - B-6).

On the average, more phytoplaniton occurred in the waters along the upper part of the bay than along the lower. Further, there was generally greater abundance at the outer stations than at the inner. These figures, along with observations, also indicate that primarily the phytoplankton was recruited from areas outside of the bay. Hence the forms are oceanic and/or neritic. At certain times, however, populations indigenous to the inner bay (Stations I, IV-VI) dominate this area. During the late summer, Peridinium trochoideum, a dinoflagellate, occurred in more abundance at the four inner bay stations while Skeletonema costatum, a diatom, was most abundant at the outer stations (II, III). During December, an increase in abundance at the inner stations was marked by a rapid rise in numbers of a green form Nannochloris atomus. At the same time, S. costatum still dominated the outer stations. Observations also showed that while the inshore stations were dominated by a single organism, the associated diatom members of the population appeared in poor physiological condition, indicated by very small chromatophores and weak silicification of the frustules.

RARITAN BAY PROJECT

TABLE B-2. DOMINANT PHYTOPLANKTON TYPES

SEP.-DEC., 1962

Station	Sep 6	Sep 20	Oct 4	Oct 11	Oct 23	Oct 30	Nov 8	Nov 27	Dec 11
I	Dinoflagellates Flagellates	Dinoflagellates	Dinoflagellates	Flagellates	No dominants	No dominants	Diatoms	Diatoms Green Algae	Green Algae Diatoms
II	Diatoms	Diatoms Flagellates	Diatoms Flagellates	Flagellates Diatoms	Diatoms	---	Diatoms	Diatoms	Diatoms
III	No dominants	Diatoms Dinoflagellates	Diatoms	Diatoms Flagellates	---	---	No dominants	Green Algae	Diatoms
IV	---	Dinoflagellates	Flagellates	Flagellates	Flagellates	No dominants	No dominants	Green Algae	Diatoms
V	Dinoflagellates	Diatoms Dinoflagellates	Flagellates	Flagellates	Diatoms Flagellates	Flagellates	Diatoms	Diatoms Green Algae	Diatoms Green Algae
VI	Dinoflagellates	Dinoflagellates	Flagellates	Flagellates	Flagellates	Green Algae	No dominants	Diatoms	Diatoms Green Algae

RARITAN BAY PROJECT

TABLE B-3. PHYTOPLANKTON GENERA AND SPECIES

September - December 1962

Organism	Station+ I	II	IIA	III	IIIA	IV	V	VA	VI
Diatoms									
Achnanthes sp.									X
Actinoptylus undulatus (cf.)		X							
Asterionella japonica		X							
Biddulphia aurita		X							
Chaetoceros curvisetus		X*							
decipiens		X							
Chaetoceros sp.		X	X						
Corethron hystrix		X		X		X			X
Coscinodiscus excentricus		X*	X			X	X	X	
subtilis	X*	X	X*	X*	X*	X	X*	X*	X*
Grammataphora marina (cf.)				X		X			
Gyrosigma acuminatum	X					X	X	X	X
balticum		X				X	X	X	
Leptocylindricus danicus				X*		X			
minimus			X						
Licmophora sp.									X
Lithodesmium undulatum		X	X						
Milosira salcata	X	X	X	X			X	X	X
Navicula sp. (cf.)	X	X	X	X		X		X	X
Nitzschia closterium		X		X					
seriata		X		X					X
Nitzschia sp.		X			X		X		X
Pediastrum sp.		X						X	
Rhizosolenia alata		X							
delicatulata		X							
hebetata semispina		X		X					
Schroderella sp. (cf.)	X						X		
Skeletonema costatum	X*	X*	X*	X*	X*	X*	X*	X*	X*
Thalassionema nitzschioides		X					X	X	
Tropidoneis lepidoptera		X					X	X	

RARITAN BAY PROJECT

TABLE B-3. PHYTOPLANKTON GENERA AND SPECIES (Concl.)

September - December 1962

Organism	Station+ I	II	IIA	III	IIIA	IV	V	VA	VI
Dinoflagellates									
Amphidinium fusiforms	X			X					
Goniaulax sp.	X*					X			
Peridinium breve	X*	X	X	X*		X*	X*		X*
Peridinium trochoideum	X*	X	X	X*		X*	X*		X*
Others									
Anacystis sp.	X*	X	X*			X		X	X*
Eutreptia sp.	X			X		X*	X*		X
Gomphosphaeria sp.	X						X		X
Green flagellate I	X*	X	X	X	X	X	X	X	X
Green flagellate II				X			X	X	
Nannochloris atomus (cf.) (green algae)	X*	X*	X*	X*	X*	X*	X*	X*	X*
Silicoflagellates	X	X		X		X	X		
Protozoa	X	X	X	X	X	X	X	X	X
TOTAL	17	24	29	20	6	16	19	15	18

+ Station I-VI, samples beginning in September; station IIA, October; and IIIA and VA, December.

* = dominants

polychaete worms (Figure B-7). Stations II and VI at opposite ends of the sampling area, were dominated by polychaetes, although the type of worm differed at the stations. It was observed that the polychaetes at Station II were of the Capitellid type, while at VI the Nereis type predominated. Amphipods also were common to all stations except VI. They accounted for 76% of the community at Station III and were numerically the second in order of abundance (Figure B-7).

At Station IV, a single organism Mya arenaria, the soft-shell clam, accounted for 92% of the population found there, also this was highest in abundance and density of any other organism or group of organisms at all stations (Table B-5). As yet no explanation can be given for the large density (42,000/m^2) at Station IV. The clams found at Station IV - VI probably represent this year's (1962) growth. At Station IV clam size ranged from 2-8 mm, while at V and VI it was 7-20 mm.

The greatest number of organisms were found at Stations III and IV, the least at VI. There appeared to be little difference among groups of organisms found at all stations (Figure B-7). However, the bivalves (pelecypods) excluding Mya arenaria, were excluded from the inner Stations IV and VI.

Abbiete (1957) found little or no macrophytic algae on the bottom sediments in the bay. Some algae occurred on pilings, buoy and lighthouse foundations and near shore substrates. The numbers of species declined towards the river.

Discussion - Phytoplankton. The low concentrations of phytoplankton in the bay during the sampling period (Figures B-1 thru B-6) suggests that factors separate from the natural environment may be responsible for the small amounts found. In comparison, in Narragansett Bay, Pratt (1959) found concentrations of 1,070-11,295 cells per ml during the late summer and fall. In Long Island Sound, Riley (1941) and Conover (1956) observed diatom blooms occurring from June - October.

Nutrients appear to be in large enough concentration (Jeffries 1962) and light penetration seemed sufficient, at least during October. At this time Secchi disc readings to 16 feet were recorded (Figures B-1 - B-6). The water was well mixed, no stratification was evident. Considering that phytoplankton composition changes periodically is no strong reason to explain the low populations here. There appeared to be sufficient light, nutrients and cells to sustain a much higher density. Further analysis of bay water and environmental variables may help to elucidate this matter.

At certain times extremely high turbidity resulted in low light penetration. The shallow euphotic zone resulting tends to

Chlorophyll. Chlorophyll a values for the associated phytoplankton counts are given in Figures B-1 - B-6. That chlorophyll and plankton counts do not correlate well is not an unusual condition in the estuary (Patten 1961). Chlorophyll a values ranged from 0.1 mg/l - 0.5 mg/l. By referring to Figure 7 in Odum (1959) where he lists the amount of oxygen assimilated/unit chlorophyll a/day for a "mixing environment" an estimate for O_2 production at the six stations can be calculated. Odum's values of 0.02 gm - 1.0 gm chlorophyll a produced 0.5 gm - 30 gm O_2/day when applied to chlorophyll amounts in the bay, give O_2 production values of 0.025 gm - .180 gm/L/day. It must be realized however, and strongly emphasized, that these amounts are gross estimates at best, because of fluctuations within the units themselves and the differences between environments.

Light Extinction. Generally, phytoplankton numbers and Secchi disc readings did not correlate (Figures B-1 - B-6). Observations revealed that the low Secchi readings (averaging 5 feet) were caused by large amounts of detritus, usually resulting from mixing after sustained high winds. Patten (1961) found the depths at which the Secchi disc disappeared ranged from 45 to 82 inches.

Benthos. At all stations except I, a red deposit, probably of iron origin was found in the bottom sediments (Table B-4). Actually, this material is fairly widespread in the Bay (H. H. Haskins personal communication). Oil in the sediments was found also at Stations III, V and VI. Although not indicated in Table B-4, a strong H_2S odor developed in all samples after standing 24 hours under refrigeration. The lowering pH levels at Stations V and VI indicate slightly acid conditions of the bottom sediments.

One hundred per cent of all soil particles from each station passed through a #18 screen (1.00 mm mesh opening). Approximately 95% of that material also passed through a #30 screen (.59 mm). This indicates the soil classification to be fine sand particles and smaller silts or clays (Hough 1957). It is the particle size of bottom sediments which frequently determines the type of organisms living therein.

A different animal community existed at each of the stations sampled (Figure B-7). That four of these stations were dominated by a single group of organisms suggests the bottom area to be fairly stable. However, in the bay different benthic communities may exist at a distance of about 100 yards apart (H. H. Haskins personal communication). At each station 84% or more of the entire animal community was composed of three or less groups of organisms (Figure B-7). At Stations II, III and VI, a single group of organisms accounted for approximately 75% of the entire population.

The most common group of animals to all stations were the

RARITAN BAY PROJECT
BIOLOGICAL DATA

STATION VI

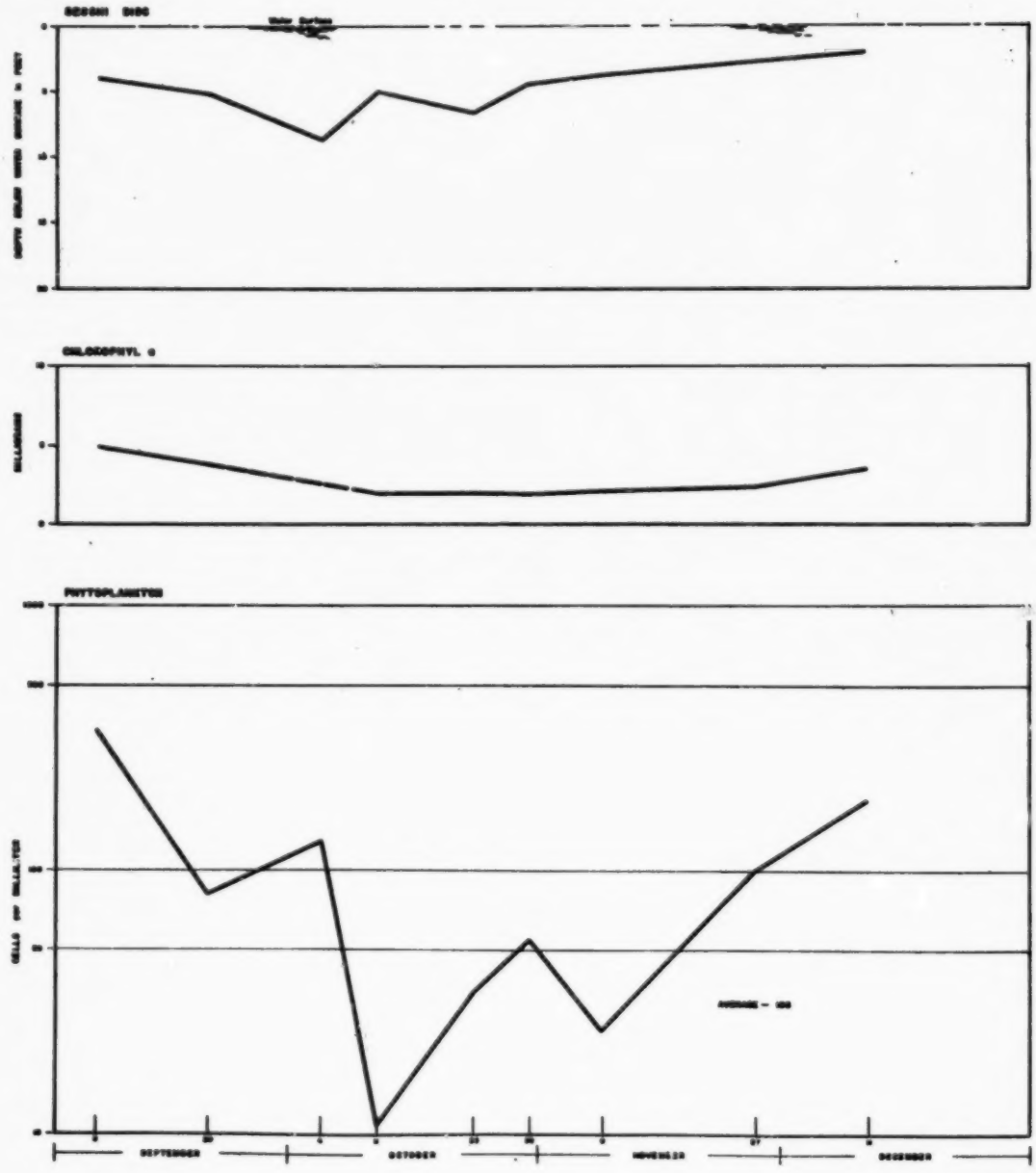

Figure B-6

RARITAN BAY PROJECT
BIOLOGICAL DATA

STATION V

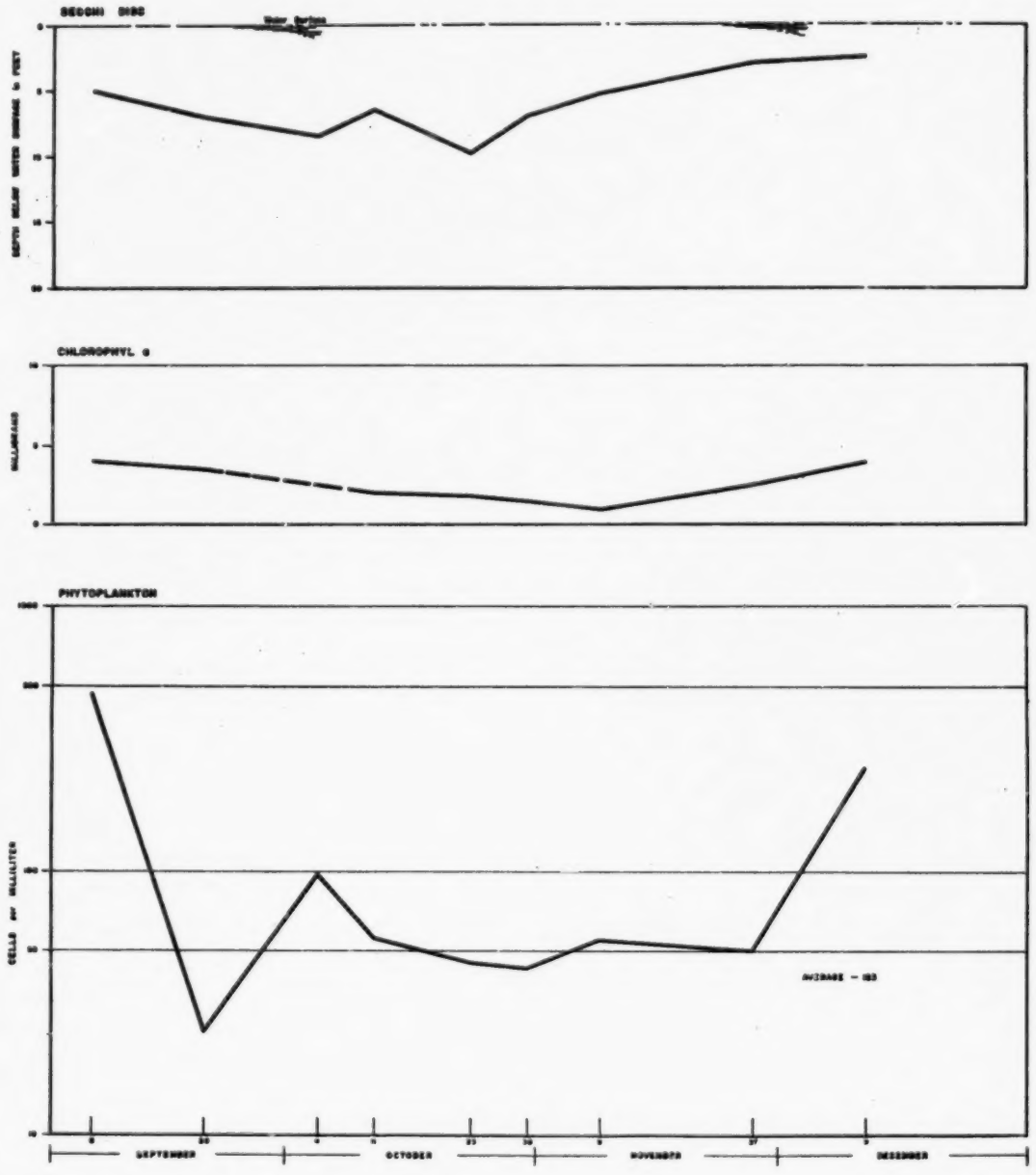

Figure B-5

RARITAN BAY PROJECT
BIOLOGICAL DATA

STATION IV

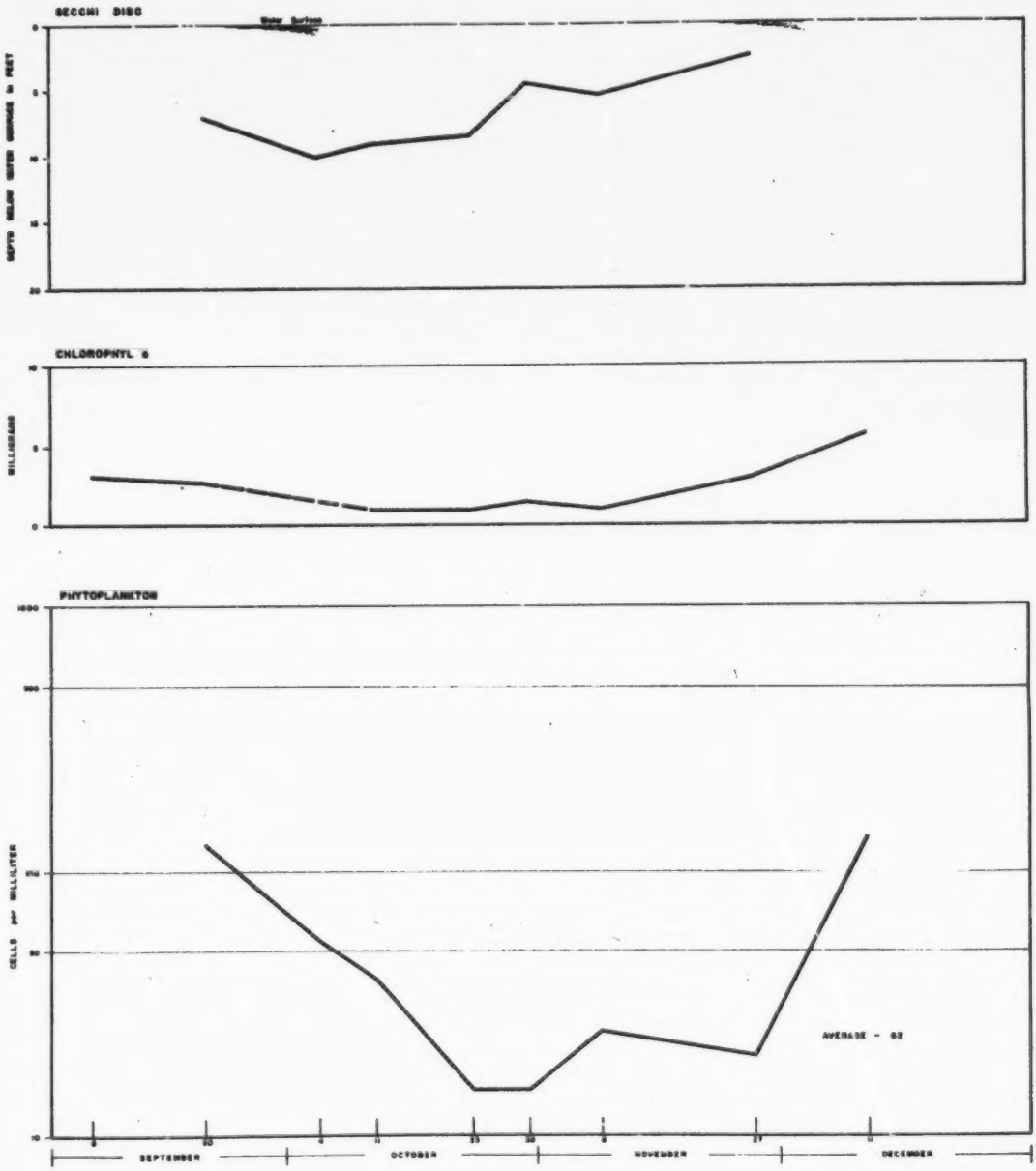

Figure B-4

RARITAN BAY PROJECT
BIOLOGICAL DATA

STATION II

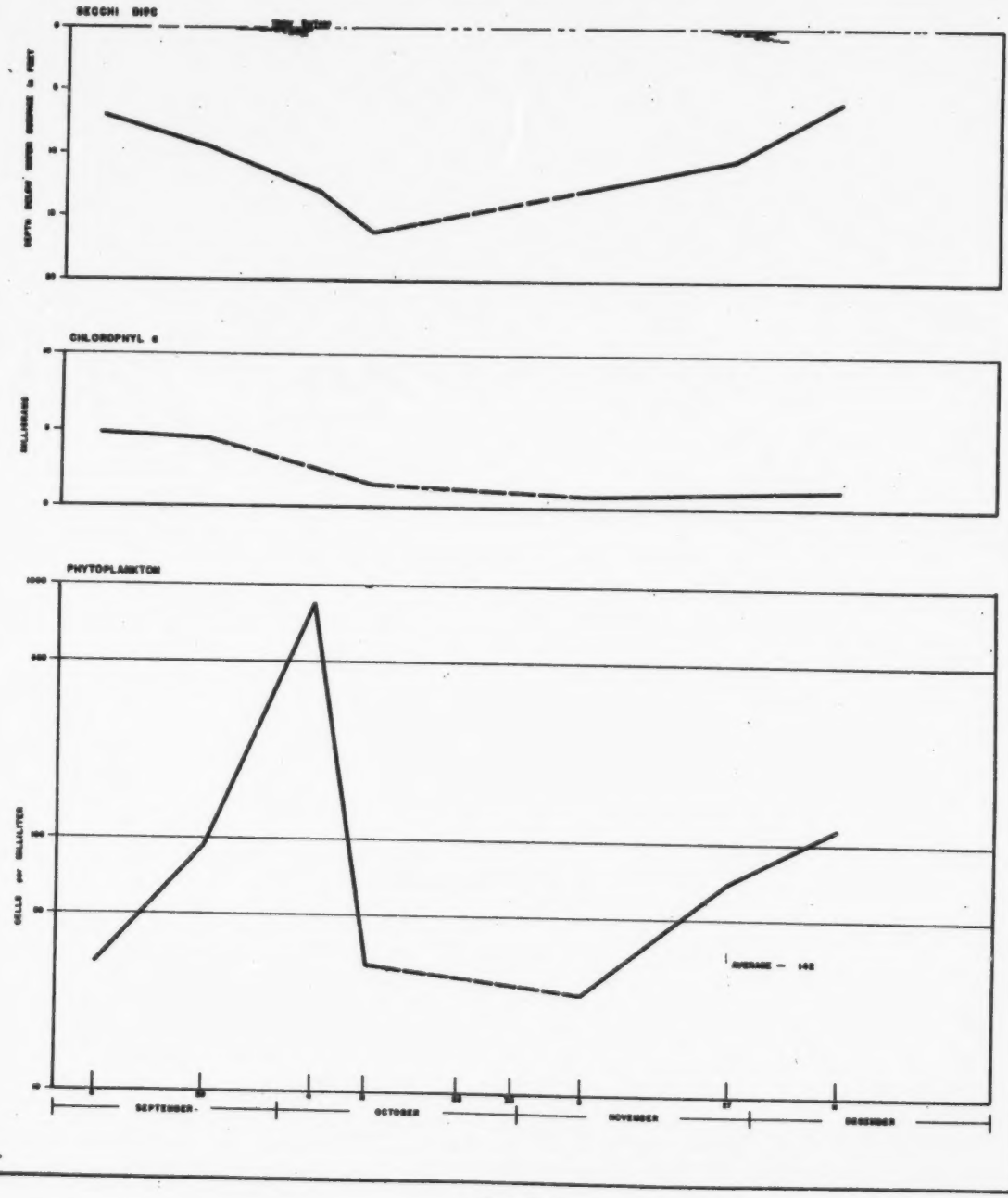

Figure B-3

RARITAN BAY PROJECT
BIOLOGICAL DATA

STATION I

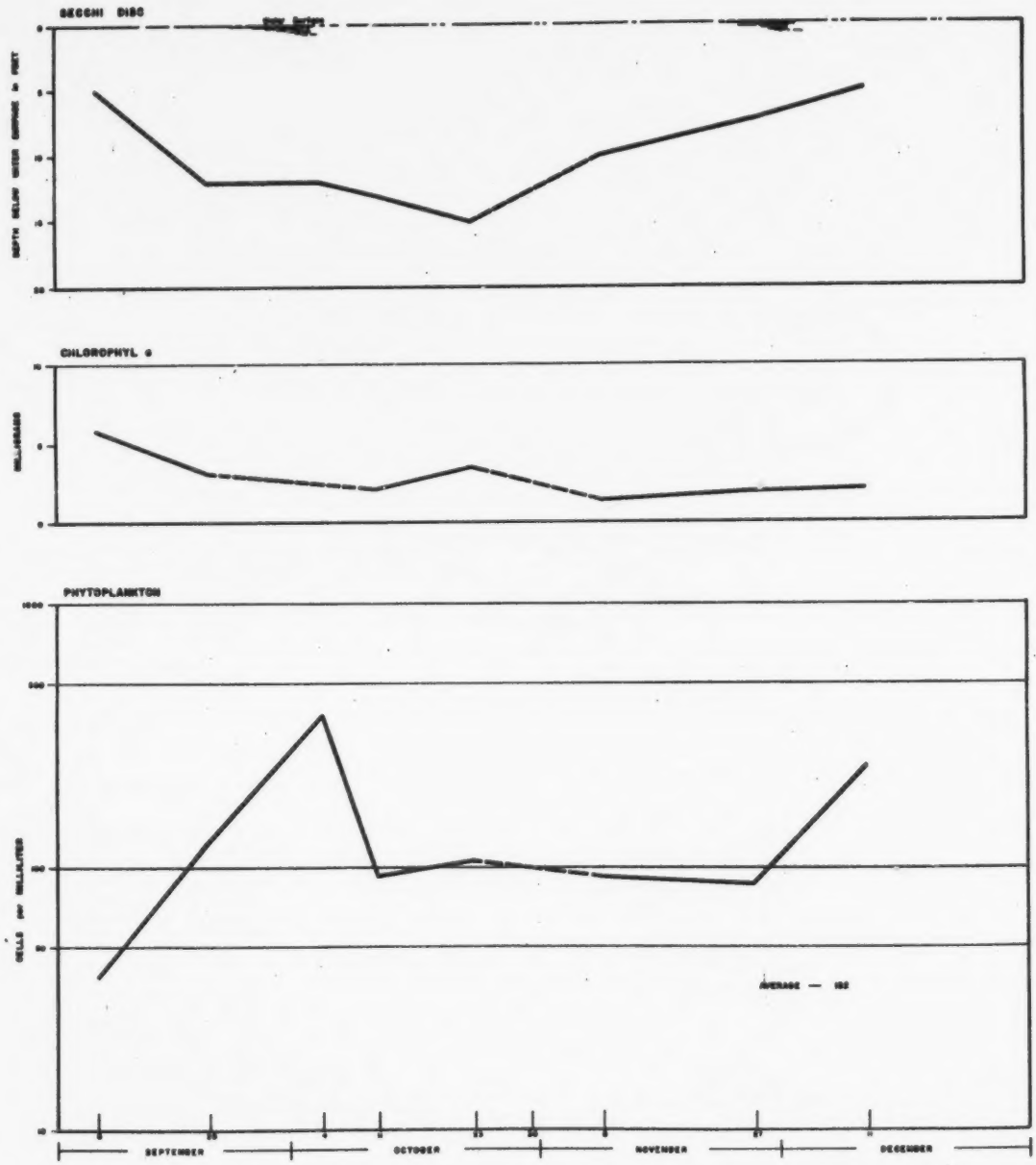

Figure B-2

RARITAN BAY PROJECT
BIOLOGICAL DATA

STATION I

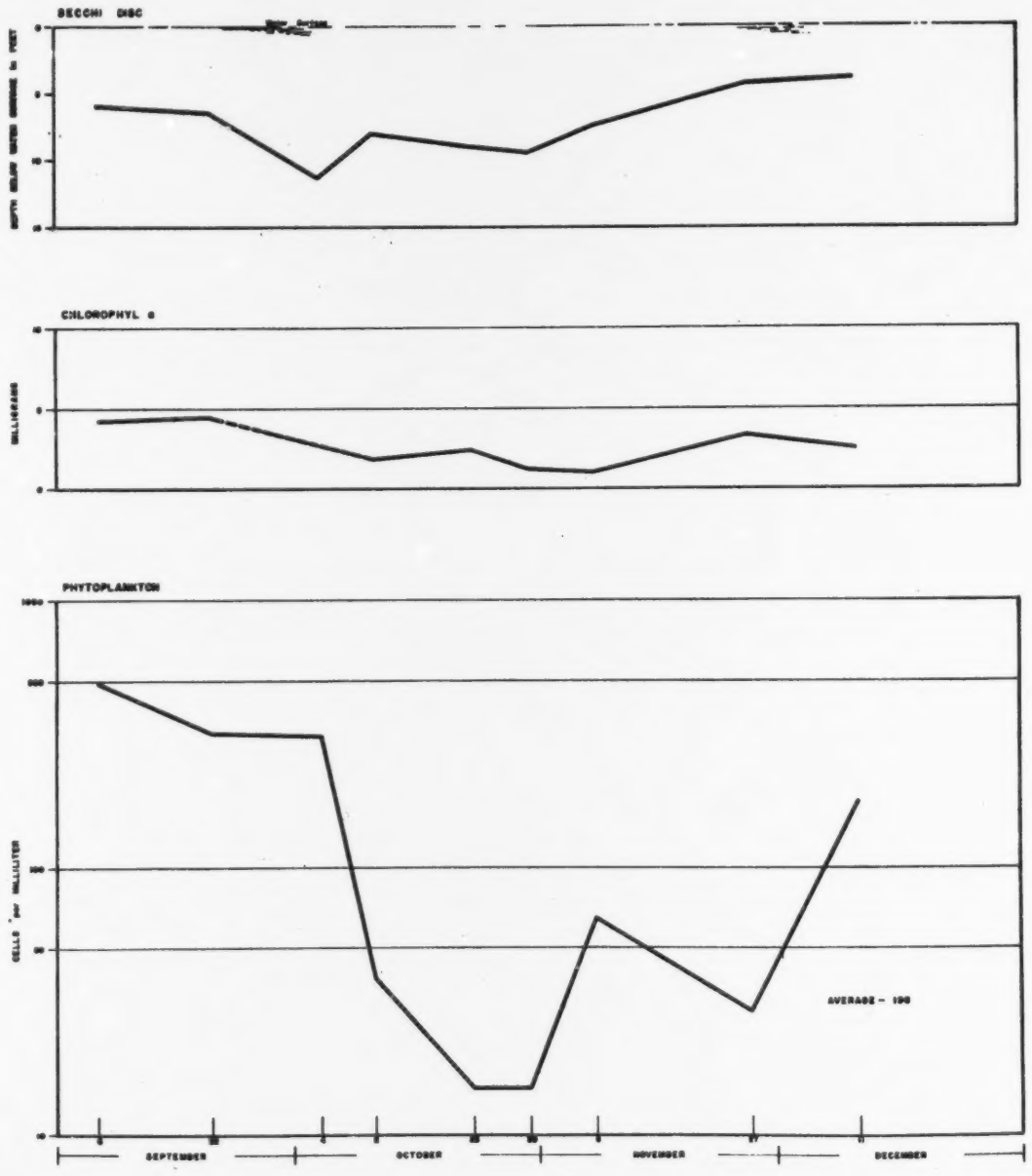

Figure B-1

RARITAN BAY PROJECT
BENTHIC POPULATIONS
COMMUNITY COMPOSITION

Percent of Total Benthic Populations

	STATION					
	I	II	III	IV	V	VI
Polychaete	6	87	20	4	27	73
Mya arenaria	-	-	-	92	42	23
Amphipoda	30	4	76	3	26	-
Isopoda	36	2	<1	<1	1	2
Gastropoda	18	5	<1	<1	2	2
Others	6	2	2	-	-	-

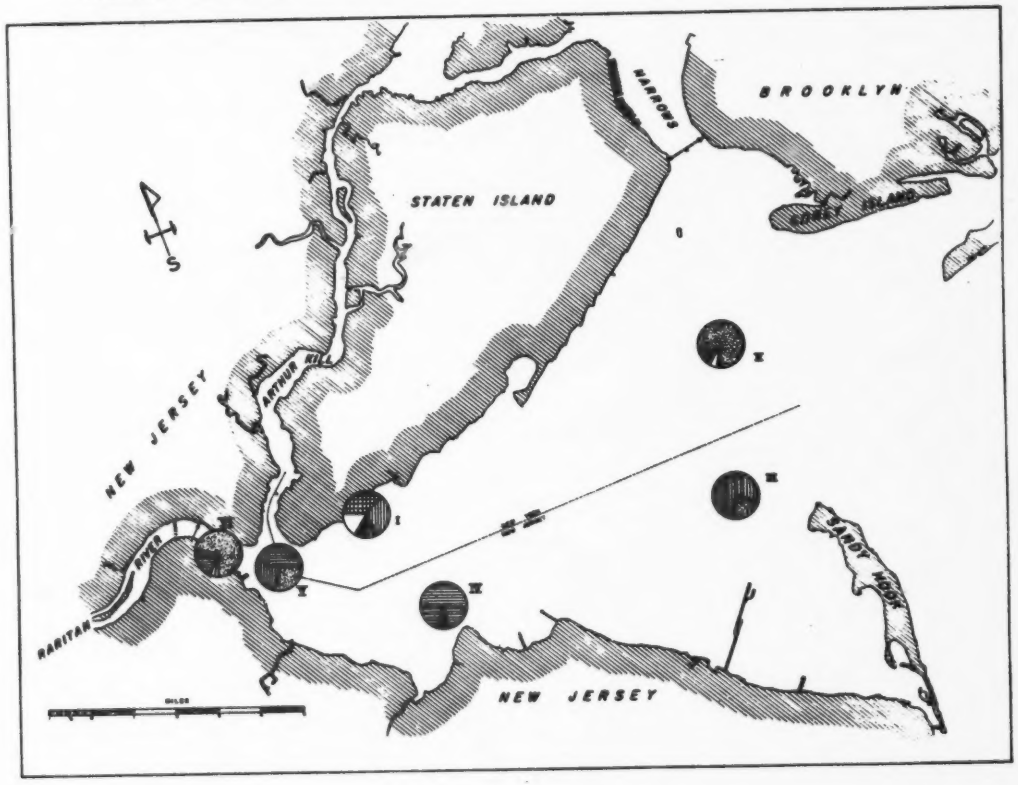

Figure B-7

RARITAN BAY PROJECT

TABLE B-4. DESCRIPTIONS OF BOTTOM STATIONS

September 20, 1962

Station	Color	Composition	Odor	Observations	Salinity Parts Per Thousand	pH
I	Black Tan	Sand, silt, shells on top, small broken shells, small pebbles (1 mm), mud.	No H_2S Musty	Amphipod tubes (organic matter) 1 cm thick on top of sample. Few large Mercenaria.	26.8	6.9
II	Black	Sand, silt, cinders, ash, soot, large mussel shells almost cover bottom, some barnacles (all dead), mud.	H_2S Musty Moldy	Rust-like material in sediment.	28.0	6.8
III	Black Brown	Sand, silt, shells, sample composed of 40-50% amphipod tubes, mud.	Slight decay Musty Moldy	Oil and rust on top of settled sample.	27.4	6.9
IV	Black Brown	Sand, silt, slightly muddy, few amphipod tubes, mucky.	Chemical moldy	Mya on top 2 cm of bottom.	25.3	6.7
V	Brown on top Black	Sand, silt, small shell and pebbles, barnacles, worm houses (1 cm depth) on top of sediment, mucky.	Oil	Oil and rust on settled sample.	25.5	6.6
VI	Brownish red to 1 cm thick Black	Silt, lot of wood slivers, very mucky.	Septic	Oil and rust on settled sample.	24.6	5.9

RARITAN BAY PROJECT

TABLE B-5. BENTHIC POPULATIONS

September 20, 1962

Density per square meter

Organisms / Stations	I	Per-cent	II	Per-cent	III	Per-cent	IV	Per-cent	V	Per-cent	VI	Per-cent
ASCIDIA (sea-squirts)			++		+						++	
BRYOZOA			++									
COELENTERATA												
Anemone					312	1						
Hydra			++									
CRUSTACEA												
Amphipods	1248	30	125	4	18408	76	1248	3	1997	28		
Isopods	1498	36	62	2	125	<1	62	<1	62	1	62	2
Decapoda (Crab)	62	2			62	<1	62	<1				
MOLLUSCA GASTROPODA (snails)	749	18	187	5	250	<1	374	1	125	2	62	2
PELECYPODA (excluding Mya Arenaria)	187	5	62	2	187	<1						
Mya Arenaria							41870	92	2933	42	749	23
NEMATODES	++		++		++		++		++		++	
POLYCHAETA	312	8	3245	87	4742	20	1685	4	1934	27	2371	73
PORIFERA (sponges)	+								+			
TOTAL	4118		3744		24149		45302		7051		3307	

+ Present, but not counted individually.

++ Abundant, but not counted individually.

reduce the amounts of chlorophyll and inhibits photosynthesis. The chlorophyll a content in bay waters is less than half found in other estuaries (Odum 1959). It appears to be advisable to conduct primary production experiments to measure the relationship among light, chlorophyll and photosynthesis here in the bay.

The occurrence during late summer of Peridinium trochoideum, a dinoflagellate, and in late fall of Nannochloris atomus, a green algae, as dominants at the inner stations, as opposed to Skeletonema costatum at the outer stations suggests that factors peculiar to the inner bay support the growth of these organisms almost to the exclusion of others. In addition, the notable differences in dominants between the inner and outer bay at certain periods indicate that the supporting water masses are different. Provasoli (1960) suggests that phytoplankton populations (growth of) may be affected by amounts of organic micro-nutrients present.

Station IV, which is in the path of outflowing river water and of ebbing tides which carry waters from Arthur Kill, sustained the overall lowest phytoplankton concentration (Figures B-1 - B-6). The concentration of cells per ml was generally less than half that of the other stations.

The greatest fluctuation in phytoplankton density occurred at Station VI (Figure B-4). This may be due to the river influence.

Benthos. The most noticeable feature of the benthic communities was the domination of bottom associations by a single group of animals. The paramount example being the large abundance (42,000/m^2) of Mya arenaria at Station IV.

When species diversity decreases and numbers of a single species increase, the ecosystem is regarded as developing toward a "climax" state. This climax condition means that the species present are the most tolerant or best "adapted" to the environment in which they are living. The less tolerant organisms do not survive. Usually in polluted or marginally polluted waters the benthic community is developing to the climax state. However, the climax condition is also present in healthy areas. Concerning the benthic fauna of the bay in regard to climax polluted conditions, no conclusions can be reached as yet. Further taxonomic study is necessary.

As with the phytoplankton, benthic fauna are signified as "indicator" organisms. It is well known that M. arenaria is able to tolerate low oxygen concentrations and other adverse environmental factors. Filicie (1959) describing an area of San Francisco Bay, divided the bottom fauna into zones. Among the organisms found in his marginal polluted zone were M. arenaria and various polychaetes. The same group of animals were found

at Stations IV - VI in Raritan Bay (Figure B-7). It is well to realize however, that this same assemblage is found in healthy bottoms to be sure, or there would be very little clam consumption.

It is not known if the large clam populations found at Stations IV and V reach adult size. There are several reasons for the doubt: (1) the large population competing for food in an area of low phytoplankton concentration, (2) oil found in the sediments (Table B-4) and the occasional "accidental" oil spillage in surrounding waters (oil clogs the feeding apparatus of the clam) and, (3) H. H. Haskins (personal communication) reports that bottom populations in the bay may shift location and change structure.

Reisch (1959) gives various accounts of investigators who assigned the polychaete Capitella capitata to areas strongly affected by domestic sewage. In the bay at Station II, the dominant group of animals were the polychaetes, many of which belonged to the genus Capitella. The definite species are unknown to the author at the present time.

Amphipods are commonly associated with shells and the tube forming types are known to exist abundantly in turbid waters (McKnulty et. al. 1959). The same conditions were found in the bay (Table B-4, Figure B-7).

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